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iMAST

Applied Research Laboratory
Institute for Manufacturing and Sustainment Technologies

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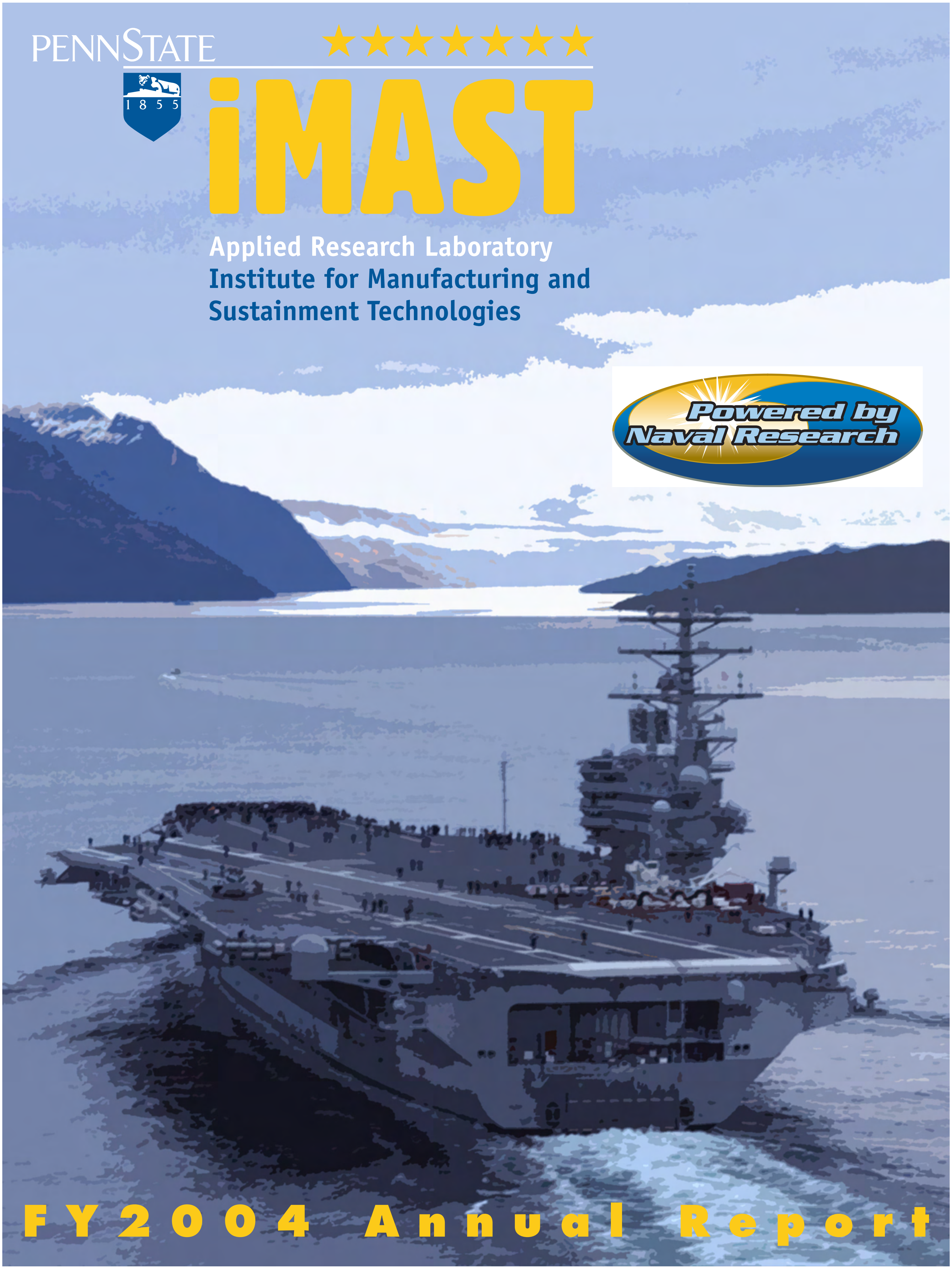

FY2004 Annual Report

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A Message from the Director

Hello. I'm hoping that you will find the time to look through this publication. In doing so, you may discover a technology that will help you. The Institute for Manufacturing and Sustainment Technologies (iMAST) is a Navy Manufacturing Technology (ManTech) Center of Excellence. The Office of Naval Research established Centers of Excellence for the purpose of providing focal points for the development and technology transfer of new manufacturing technology, processes, and equipment in a cooperative environment with industry, academia, and the Navy centers and laboratories. Navy ManTech Centers of Excellence:

- serve as corporate residences of expertise in particular technological areas;
- develop and demonstrate manufacturing technology solutions for identified Navy manufacturing requirements; and
- facilitate the transfer of developed manufacturing technologies to the U.S. industrial base.

This report describes six technical areas that are resident in the Materials and Manufacturing Office of the Applied Research Laboratory, Penn State. Along with technologies, descriptions of completed and ongoing projects are provided. These are representative examples of our competencies. In addition, we have the resources of The Pennsylvania State University available.

This year has been one of transition. iMAST's focus has shifted to supporting the new design carrier. As such, we have been working with the program office and the shipbuilder, Northrop Grumman Newport News. By maintaining an open dialogue with the program office and the prime contractor, the prospect of implementing technology in the next generation carrier is promising.

We are a Navy asset. We are here to help. Take advantage of us!

Bob Cook
ManTech Program Director
ARL Penn State

iMAST Annual Report FY04

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"We owe our Sailors and Marines who will go into harm's way every edge technology can provide. Technology will never be a substitute for courage and human toughness in conflict, but it can increase the likelihood that the tough and the courageous will be successful."

—Admiral William A. Owens, USN

Institute for Manufacturing and Sustainment Technologies

iMAST is a Department of the Navy Manufacturing Technology (ManTech) Center of Excellence located at The Pennsylvania State University's Applied Research Laboratory in State College, Pennsylvania. Formally established in 1995, the institute is comprised of seven technical thrust areas:

- **Mechanical Drive Transmission Technologies**
- **Materials Processing Technologies**
- **Laser Processing Technologies**
- **Advanced Composites Technologies**
- **Manufacturing Systems**
- **Complex Systems Monitoring**
- **Repair Technology**

iMAST provides a focal point for the development and transfer of new manufacturing processes and equipment in a cooperative environment with industry, academia, other Navy acquisition, and in-service use. The Institute leverages the resources of The Pennsylvania State University to develop technology and business practices that enhance the industrial sector's ability to address advanced weapon systems issues and challenges for the Department of Defense. Sponsored under Navy contract N00039-97-0042, iMAST provides manufacturing technology support to the systems commands of the U.S. Navy and Marine Corps.

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Mechanical Drive Transmission Technologies

Technology Leader: Dr. Suren Rao

Mission

To assist in the enhancement, revitalization, and resurgence of the transmission industrial-base sector of the United States. This assistance is necessary for several reasons. It is essential that this particular industrial base remains viable, competitive, and robust in order to effectively address U.S. Navy, Marine Corps, and DoD modernization and surge requirements. Further, this industrial sector is critical to the national transportation infrastructure and, therefore, needs to remain responsive and competitive to address national interests. In order to achieve the stated objectives, iMAST needs to be recognized as a national resource. Since it is the industrial sector that supplies the DoD with mechanical drive transmission components and systems, it is essential that this recognition be derived from both industry and government sectors alike. The broad technological objectives driving the research and development agenda of iMAST are noted by the following stated DoD goals:

- Reduce transmission weight by at least 25 percent
- Reduce vibration and noise by at least 10 dB
- Increase MTBR (mean-time-between-removals) by 20 percent
- Reduce procurement and operating costs (affordability)

Continued influx of industrial, dual-use sponsored research has been a prominent feature of the Drivetrain Technology Center during this current year. Featured among them has been the program to qualify ausform finishing for aerospace gears sponsored by Boeing Mesa, with partial support from the ONR DUS&T program and a variety of smaller projects from industrial organizations such as New Venture Gear, John Deere, Genesis Corporation, and Harley Davidson. Also active have been evaluation programs for new materials for gear applications including powder metal alloys and high-hot-hardness steels.

These projects are the direct result of establishing one of the most comprehensive testing and evaluation facilities in the nation for gears and gear materials at the Drivetrain Technology Center, together with a state of the art gear metrology facility. This metrology laboratory includes a one of a kind M&M OP 9000 CNC (Computer Numeric Control) Gear Measuring Machine with two measuring stations. One station is based on a conventional touch probe and the other is based on the optical gear tooth measuring system, being developed at ARL.

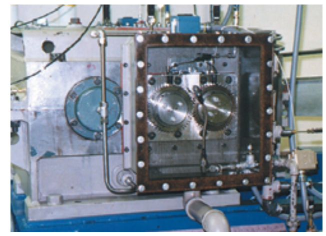
The mechanical drive systems transmission thrust areas include the following:

- Develop advanced manufacturing processes and equipment
- Improve current manufacturing techniques
- Evaluate advanced hot-hardness steels for improved performance
- Characterize impact of materials and related processing on component strength and durability
- Characterize impact of component accuracy on performance
- Develop improved metrology equipment and techniques for enhanced component accuracy
- Analysis of drive systems designs for improved performance

Unique Capability
Drive System Component Materials Testing is an essential requirement to validate process qualification in support of high-performance transmission technology. Rolling Contact Fatigue (RCF) testers for simulating gear tooth contact, Single Tooth Fatigue (STF) testers for evaluating bending fatigue, and Power Circulating (PC) testers for contact fatigue testing on gears are essential equipment. ARL Penn State has one of the most comprehensive and unique

collections of transmission testing equipment in the United States. Both RCF and STF testing can be conducted at temperatures of up to 400°F. Variable PC testing under load can be conducted from as low as 900 rpm to as high as 10,000 rpm at up to 1,400 hp.

Performance Testing of Ausform Finished Gears



The objective of this project is to evaluate the surface durability and strength of ausform finished gears as compared to conventionally processed gears. Program tasks include developing the tooling and process parameters to ausform finish the 48 teeth, 6" PD test gears. The second phase of the program involves developing specialized tooling and processing techniques to enable ausform finishing of the root/fillet regions of the gear teeth, in addition to the tooth flanks. Pitting and bending fatigue as well as scoring resistance of test gears will be evaluated to establish the performance enhancement of ausform finished gears as compared to ground gears. The project will establish the quantitative design information that will facilitate implementation of the process for high performance drive train applications. The project is applicable to transmission components used in air, surface, undersea and ground combat weapon systems, and Boeing Mesa is actively participating in the program with cash and in-kind support.

Experiments to optimize the rolling die tooth profile for ausform finishing were conducted during the year and after five iterations a final die tooth grind is currently in process. These experiments have clearly shown that achieving tooth accuracy for aerospace gears (AGMA Class 12 and better) will be significantly aided by the development of a process model. These verified analytical process models will enable the definition of die tooth geometry, required to achieve that level of gear accuracy, with a minimal number of iterations. The effort of developing process models for ausform finishing forms a significant part of the Boeing Mesa/ONR sponsored DUS&T program, currently underway. Fatigue testing of base line gears and design of rolling dies for root rolling development have been accomplished, as a part of this effort, in the last year.

Project Leader: Dr. Nagesh Sonti

Ausform Finishing of Bearing Races

The objective of this project is to evaluate advanced surface enhancement techniques including ausform finishing in conjunction with multilayered coatings to enhance surface durability, wear and corrosion resistance, and thereby, the mean-time-before-overhaul of transmission bearings. Enhanced surface strength due to ausforming has the potential to substantially improve the power density of transmission bearings. The project will develop the tooling and processing techniques for bearing raceways, and involve comprehensive bearing testing to establish the comparative performance of surface enhanced bearings. The project is structured with substantial in-kind contribution from Rexnord in terms of specimen manufacture and bearing endurance testing. Project supports multi services and multi weapon systems, and the demonstration component is a cylindrical roller bearing from AAAV main transmission.

Experiments to optimize the rolling die tooth profile for ausform finishing were conducted during the year and after five iterations a final die tooth grind is currently in process. These experiments have clearly shown that achieving tooth accuracy for aerospace gears (AGMA Class 12 and better) will be significantly aided by the development of a process model. These verified analytical process models will enable the definition of die tooth geometry, required to achieve that level of gear accuracy, with a minimal number of iterations. The effort of developing process models for ausform finishing forms a significant part of the Boeing Mesa/ONR sponsored DUS&T program, currently underway. Fatigue testing of base line gears and design of rolling dies for root rolling development have been accomplished, as a part of this effort, in the last year.

Project Leader: Dr. Nagesh Sonti

Unique Capability
Ausform Finishing is the process of heating a case-hardened steel specimen to a red-hot temperature, quenching it to a working temperature, followed by rolling it to maximize strength and geometry. ARL Penn State possesses the world's only production-capable double-die ausform finishing machine.

Non-Contact Workpiece Positioning System

The ultimate objective of this project is to reduce costs and lead-time in the machining of large precision drive train components such as transmission housings. The approach being pursued, under this program structure, is to eliminate the use of physical surfaces on the component as datum. The use of physical surfaces as datum during machining is a methodology that has remained unchanged since the dawn of machining and is susceptible to creating inaccurate parts due to variety of reasons. Some of these reasons are inaccuracies in the datum surfaces themselves, ingress of chips, burrs and dirt between matching datum surfaces, etc. In spite of a significant amount of care being currently exercised in the manufacture of such components, to overcome these problems, high scrap rates are not uncommon. Further, the use of physical datum surfaces for precision machining requires the design, manufacture, storage and retrieval of very expensive, part specific work holding tooling. All the drawbacks of this methodology, listed, results in excessive costs in the manufacture of these components and very long production lead times.

The solution being explored is to develop the methodology of defining a "VIRTUAL" datum on the part before machining and the methodology to identify this datum on the machine tool before initiating the machining part program. This would enable the part program to be exercised for where the part is, on the machine, thus resulting in a more accurate part in less time.

This methodology, utilizing a laser-triangulation probe has been developed on a 5-axes machining center and shown to be capable of machining the 3 primary bores of SH-60 main transmission input housing in about half the time while maintaining the specified part print accuracy between the bores. This system was demonstrated to Sikorsky Aircraft and Navy personnel on the 5-axes Machining Center at ARL's Garfield Thomas Water Tunnel machine shop. Based on the successful demonstration Sikorsky Aircraft is planning an installation at its Stratford facility and is evaluating various alternate schedules, based on their shop load, to implement the Non-Contact Workpiece Positioning System. Once the time frame is selected an "industrially hardened" system will be installed on a select machine tool at Sikorsky Aircraft.

Project Leader: Dr. Suren Rao

In-Situ Gear Error Measurement

At the request of the Naval Sea Systems Command, the development of a method of measurement and associated signal processing for precision determination of the amplitudes of gear tooth undulation errors was completed and programmed on a digital computer. The method was tested and successfully used for in-situ measurement of undulation-error peak-to-peak amplitudes in the range of 0.01 to 0.30 microns (meters $\times 10^{6}$). Also, a method for computing the "influence functions" of gear tooth elastic deformations on lines of tooth contact, including accurate computation of the local contact (Hertzian) component of deformations, was completed and successfully implemented on a pair of helical gears.

Project Leader: Dr. William D. Mark

Unique Capability
A Navy Metrology Laboratory located at ARL Penn State provides the U.S. Navy with a neutral or "honest broker" testing site for verifying measurement accuracies related to gear specifications. This capability is fundamental and basic for the advancement of mechanical drive transmission manufacturing science and technology. The laboratory provides the Navy with an on-call 48-

hour resident resource for addressing gear metrology technical issues related to naval weapon systems platforms.

Accelerated Capabilities Initiative: Machinery Diagnostics and Prognostics

(Non-ManTech)

A team of iMAST engineers continue to address condition-based maintenance (CBM) capabilities related to producing a CBM capability demonstration on a Navy weapon systems platform. The team continues to develop a new hybrid modular smart device for monitoring the condition of complex mechanical equipment. The team has been given access to unique test facilities and domain expertise provided by NSWC Philadelphia and NCCOSC San Diego. The Ben Franklin Technology Center of Southeastern Pennsylvania continues to support the technology transfer effort to industry.

Project Leader: Carl Byington

Unique Capability

Gear Performance Prediction indicates transmission error of meshing gear pairs by identifying vibratory excitation caused by gear tooth geometry imperfections and elastic deformation. ARL Penn State has developed a method to rigorously predict from first principles the transmission error contributions from detailed generic descriptions of gear tooth geometric imperfections (measured by dedicated gear metrology equipment).

Technologies for Gear Performance Prediction Using Precision Optical Measurement

(Non-ManTech: A NIST Advanced Technology Program Project)

M&M Precision Systems Corporation of Dayton, Ohio and the Drivetrain Technology Center proposed and were awarded a technology project to rapidly measure and quantitatively relate gear-tooth errors to gear performance, thereby providing to gear manufacturers and builders of gear manufacturing equipment the capability to focus on controlling those error patterns on gear teeth that are significant sources of vibration, noise, and other imperfections in the functioning of meshing gear pairs. A high-speed optical sensor capable of obtaining topographical measurements of manufacturing error patterns on gear teeth will be developed as part of this project.

A NIST ATP program was awarded to M&M Precision Systems Corporation, manufacturer of precision CMM touch probes. ARL is subcontractor to M&M for both the noncontact optical sensing system as well as gear performance prediction capabilities based on the optical measurements. The M&M program involves enhancement of gear optical inspection calibration techniques to provide absolute measurement capabilities.

Project Leaders: Dr. William D. Mark and Dr. Karl Reichard

Process Development of Advanced Gear Steels for High-Performance Transmission Application

(Non-ManTech)

This project continues to evaluate the durability, fatigue strength, and scoring resistance of selected advanced gear steels for air vehicle and turbine engine applications. The project tasks include heat treatment and manufacturing process optimization; manufacture of precision gear test specimens; dimensional and metallurgical test specimen inspection before-and-after testing; single tooth bending fatigue testing, rotating surface fatigue testing, scoring resistance testing; and the establishment of a comprehensive advanced gear steel data base for use by design engineers. The project is funded by an advanced materials coalition of ten industrial members including Allison Engine Company, Allvac (An

Allegheny Teledyne Company), Arrow Gear Company, Bell Helicopter Textron, Boeing Helicopters, Boeing Precision Gears Incorporated, Carpenter Technology Corporation, Latrobe Steel Company, Sikorsky Aircraft Corporation, and The Purdy Corporation.

This program will develop affordable improved fatigue- and scoring-resistant materials for high-performance drive system components including gears, bearings, and shafts. Reliable materials manufacturing processing data will be established, as well as fatigue and scoring resistance data which is required by design engineers for improving power density, reliability, and life-cycle-cost drive systems. Concurrent investigation of four advance steels was conducted throughout the year and will continue into fiscal year 2000.

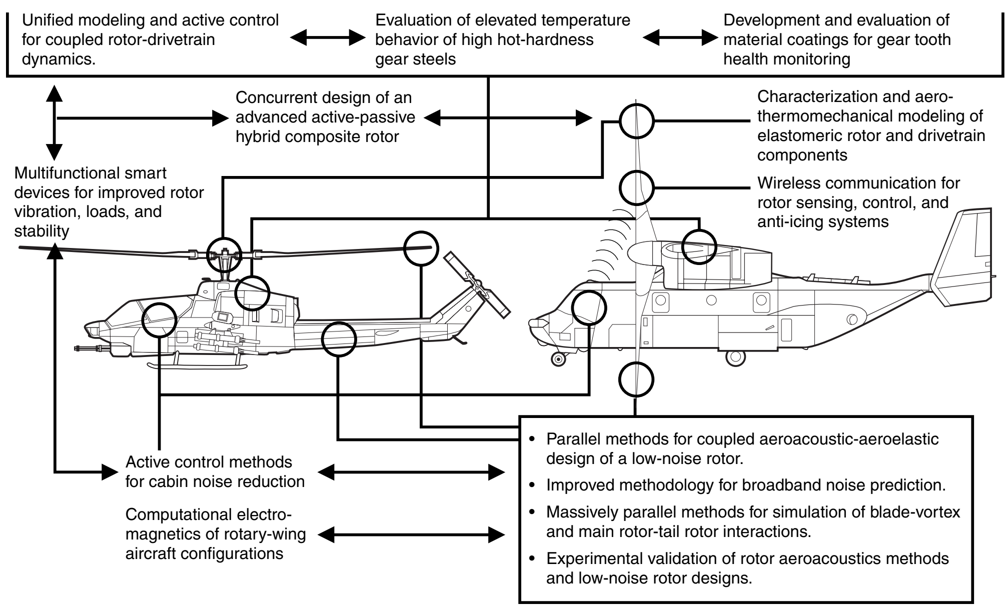
Project Leader: Dr. Nagesh Sonti

Penn State Rotorcraft Center of Excellence

(Non-ManTech)

iMAST continues to play a supporting role with Penn State's Rotorcraft Center of Excellence. The center of excellence is one of three centers in the country that conduct long-term basic and applied research in rotorcraft technology. Projects related to iMAST's mechanical drive transmission technologies include, evaluation of elevated temperature behavior of high hot-hardness gear steels, unified modeling and active control methods for coupled rotor mechanical drive system dynamics, and development and evaluation of material coatings for gear tooth health monitoring.

Project Leaders: Dr. Tom Donnellan and Greg Johnson



Gear Research Institute

Gear Research Institute
ASME & AGMA Institute affiliated with Penn State

Co-located with the Drivetrain Technology Center at Penn State, the Gear Research Institute provides additional expertise relative to mechanical drive transmission efforts ongoing at the Applied Research Laboratory. Although not affiliated with the Navy ManTech Program, the Gear Research Institute, which is sponsored by industry, provides a conduit for Navy ManTech since partnering with industry is an essential element of the program.

A not-for-profit corporation, the Gear Research Institute is organized to provide and supplement gear-related technology requirements by conducting research and development, consulting, analysis and testing. The Institute is a leading proponent of Cooperative Pre-Competitive Research. When requested, however, it also serves individual companies. Since its inception in 1982, the Gear Research Institute has conducted technology programs in the following areas:

- Austempered Ductile Iron
- High-Hot-Hardness Gear Steels
- Utilization of Boron Toughened Steels
- Technology Surveys
- Durability Testing of Gears
- Effect of Lubricant on Durability
- Induction Hardening of Gears
- Effect of Surface Finish on Durability
- Heat Treat Distortion
- Finite Element Modeling

Over the last two decades extensive research and test data has been accumulated and published in a large number of reports to the sponsors. The Gear Research Institute has all its research and other related activities conducted at Penn State's Applied Research Laboratory.

Test Facility

The Gear Research Institute is equipped with state-of-the-art test capabilities. These include Rolling Contact Fatigue (RCF) testers for low and high temperature roller testing, Power Circulating (PC) gear testers for parallel axis gears with a 4-inch center distance (testers can be modified to accommodate other center distances), Single Tooth Fatigue (STF) testers for spur and helical gears, Single Tooth Impact tester, and worm gear testers with 1.75- and 4-inch center distances. Extensive metallurgical characterization facilities are also available at Penn State, in support of the Gear Research Institute.

Current Sponsors

The activities currently underway are under the sponsorship of three research blocs. The sponsorship of each bloc is the following:

Aerospace Research Bloc

Boeing Helicopters
Pratt & Whitney
Avio Group
REM Chemicals
Rolls Royce
Honeywell
Purdy Corporation
Sikorsky Aircraft

Vehicle/Industry Research Bloc

Dana Corporation
Eaton Corporation
REM Cemicals
General Motors
New Venture Gear

Efforts are currently underway to establish a bloc focused on evaluating hard coating systems for power transmission applications.

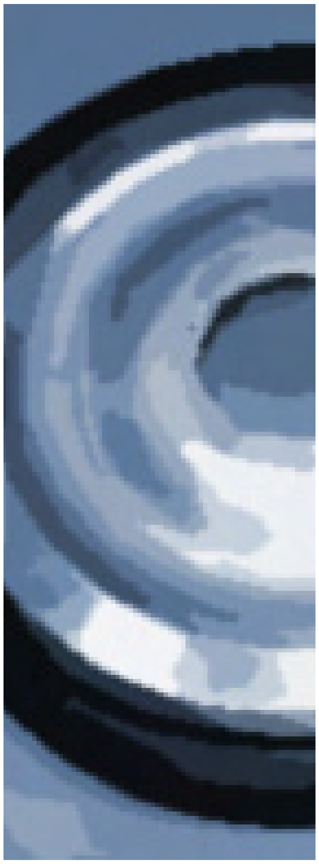
Trustees and Committees

The Gear Research Institute is governed by a tripartite Board of Trustees representing the membership of the Institute, the American Society of Mechanical Engineers (ASME), and the American Gear Manufacturers Association (AGMA). For the research effort, each Research Bloc creates its own Steering Committee whose responsibility is to select and guide programs within their respective bloc.

POC: Dr. Suren Rao

Materials Processing Technologies

Technology Leader: Dr. Tim Eden (acting)



Mission

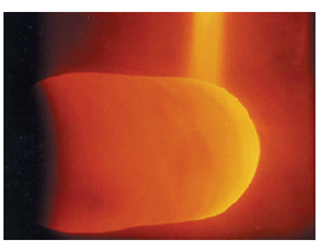
To perform applied research, development and engineering on materials and materials processing in support of the manufacturing requirements of the Department of Defense and the domestic industrial base. To satisfy these requirements, ARL Penn State has capabilities in advanced metals and ceramics development, materials processing, electronic materials and surface technologies. Our focus is to act as a leader in the field of material science by providing innovative solutions to the material technical challenges of today and tomorrow. Our goal is to minimize the acquisition and life cycle costs of DoD weapons and support systems.

The Material Processing Division had several Navy/Marine Corps ManTech projects on-going during the fiscal year showing the wide technical base, knowledge, and vast expertise of division personnel. The objective of each program is to provide a complete material solution. On all the programs the root cause of the problem or final component properties are determined. A solution is then identified and a technical program developed for implementation to realize the objectives. In programs such as the AAV Appliqué Armor Kit Product Improvement program, a procedure was developed to improve the corrosion resistance of the armor. Four sets of armor were treated and are being installed for a long term deployment to validate the process.

The materials processing thrust is organized into two departments:

- Metals and Ceramic Processing
- Advanced Coatings

Technical capabilities include coating for corrosion resistance, wear resistance, thermal barriers, environmental barriers and functional tailoring of materials and laminate structures. Division technology has been applied to near-net shape forming of high temperature materials and nanomaterials.



Unique Capability

Spray Metal Forming is a rapid solidification process that can significantly enhance the properties and microstructures of engineering alloys and can also create new alloy compositions not possible using conventional processes. The process begins with the atomization of a metal stream with inert gas. The stream, collected onto a plate or mandrel, is sufficiently void free and can be used in the as-sprayed condition or further processed by forging, extrusion, or rolling. The ARL Penn State spray metal forming plant is a multi-use pilot plant that can spray both ferrous and non-ferrous alloys. The plant has the capability to spray form materials into billets, sheets, and tubes. It is the only plant in North America dedicated to the development and optimization of high-temperature and high-strength aluminum alloys. ARL is currently producing high-strength alloys with yield strengths of 100 ksi and ductility between 9 and 13%.

Advanced Manufacturing Processes for Advanced Amphibious Assault Vehicle (AAAV) Roadwheels

This project is evaluating manufacturing technologies to provide component weight savings and improve maintainability on the roadwheel system of the AAAV.

High-Velocity Particle Consolidation (HVPC) will be evaluated as a coating process for the AAAV roadwheels. Using HVPC as a means to put down a sacrificial wear coating on the roadwheel has the potential of providing an additional 415 pounds in combined weight savings when compared to the current steel wear ring.

Project Leaders: Dr. Tim Eden

Unique Capability
Micro- and nanofabrication manufacturing technologies comprise the set of base technologies essential to the manufacture of micro- and nanoscaled electronic integrated circuits. These technologies include materials deposition, materials etching, and materials modification. ARL Penn State has unique access to state-of-the-art nanofabrication facilities. These facilities are located in Penn State's Research Park and contain over 3,600 square feet of class-1,000 clean rooms and 1,400 square feet of class-100 and class-10 clean rooms. These clean rooms contain the latest equipment for electron beam lithography, low-pressure chemical vapor deposition (CVD), plasma-enhanced CVD sputtering deposition, plasma and reactive ion etching and rapid thermal annealing tools. This facility can duplicate production environments for the manufacture of microcircuitry, flat panel displays and microelectromechanical devices (MEMs).

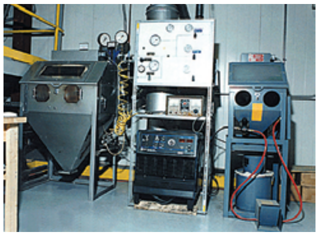
Unique Capability
Nanograined materials technology deals with material particles below .5 microns. Taking advantage of recent advancements in nanograined powder production, ARL Penn State has focused its efforts on the consolidation of these nanograined powders into fully densified preforms (cutting tool blanks and inserts). The consolidation of the powders has been accomplished by a combination of microwave sintering and vacuum hot-pressing. The results are fully densified nanograined preforms fabricated into cutting tools used to mill titanium alloys.

AAV Appliqué Armor

In this project, the corrosion mechanisms for the appliqué armor were identified, and methods were developed to mitigate the corrosion on the armor currently in use, and suggestions were made on how to improve the manufacturing process to make the armor more corrosion resistant. The investigation into the corrosion mechanism included visits to the marine bases where the armor was used to gain an understanding of the operating conditions that the armor is exposed to, how the armor is stored and maintained, and issues the AAV units face in using the armor. From these interactions, coating requirements were developed. One of the main requirements was that the corrosion coating had to be very damage tolerant.

Several different coatings including organic and inorganic primers, zinc, aluminum and zinc/aluminum coatings were tested in an alternate immersion corrosion test. The coatings on several of the samples were damaged to represent damage that would occur in the field. The aluminum coating provided the best corrosion resistance and had good damage tolerance. Two sets of armor (70 panels per set) were coated with aluminum using high velocity particle consolidation (HVPC), sealed and coated with CARC. Two additional sets were coated with aluminum using wire-arc thermal spray, sealed and coated with CARC. The armor was taken from inventory. These four sets along with two sets of new armor provided by the armor manufactured are being tested in a long term deployment. Results of the long term deployment showed that the aluminum coatings provided corrosion protection to the AAV armor. The deployment also showed that the HVPC coating performed better than the thermal spray coating. The results showed that this process can be used to extend the life of the armor already in use.

Project Leader: Dr. Tim Eden



Unique Capability
High-Velocity Particle Consolidation (HVPC) is a coating technology that originated in the former Soviet Union. This technology has been transitioned to the U.S. domestic industrial base. The technology is based on the supersonic acceleration of coating particles, which imbed themselves into a substrate, causing a coating to build based on friction welding. The process operates below the melting threshold of both the particles and the substrate, thus there is a good bond strength between coating and substrate, with no substrate melting or recrystallization. Benefits include allowance for the alloying of coatings, high productivity and high deposition rate, and deposition efficiencies up to 80 percent. The R&D facilities that support this technology are unique in that they provide the capability to lay down coatings as thin as 0.0005 inches to as thick as several inches. ARL Penn State has full rights to the coating process.

F/A-18 F404 Fretting and Low-Cycle Fatigue Amelioration

This project is evaluating fretting and low-cycle fatigue that adversely affects the compressor and fan sections of the F404 engine. The current configuration of the titanium fan blade and the titanium fan disk provides for a copper-nickel-indium coating on the blade root. This coating fails, causing the titanium to titanium wear, a process that leads to fretting and low-cycle fatigue. If not discovered in time, this wear can lead to catastrophic failure of the compressor section.

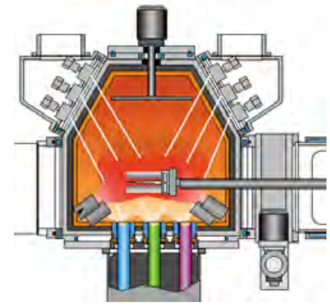
The project is evaluating the failure mechanisms of fretting and low-cycle fatigue and duplicating them in a laboratory environment. After establishing the baseline failure configuration, an optimum coating and/or coating process will be developed and implemented, and will eliminate/minimize fretting and low-cycle fatigue and the blade-disk interface. This optimum coating and/or coating process will be evaluated both in the laboratory and in actual fleet testing.

A capability supporting this project effort is adverse wear amelioration through advanced coatings designs and/or coating processes. By integrating capabilities resident throughout Penn State, considerable expertise can be focused on addressing the testing and evaluation of coatings and coating processes.

The dove tails of three blades were coated with Molybdenum (Mo) and the dove tails of three additional blades were coated with Nickel (Ni). Four of the blades were coated with a boron-nitride high temperature dry lubricant and two were coated with Sol-gel. Six blades were coated with copper-nickel-indium (CuNiIn). Three blades were coated with Moly-dag lubricant. These blades were used as the base line for an engine test. Three blades were coated with boron-nitride lubricant. The blades were tested in a Pegasis engine as part of a ASMAT engine test. The blades that were coated with Mo and Sol-gel had the best performance.

Project Leader: Dr. Tim Eden

Aircraft Carrier Arresting Gear Poured Cable End Sockets



The goal of this project is to find a potting material that can replace the zinc in potting the arresting gear cable end sockets to the arresting gear cable. The use of zinc as a potting material can lead to hydrogen embrittlement of the cable. The new material had to have a reduced potential for hydrogen embrittlement, have a cure or process temperature equal to or lower than zinc, and have to have similar processing time. Several candidate materials were tested in subscale specimens. The epoxy system Epon 862/ Epon 58005/ Epi-Cure 9552 /TS-720 binder performed the best in both quasi-static and dynamic tests. The tests were conducted over the temperature range of -15°F to 150°F. Full-scale cables are being formulated. Six sections of cable, four feet long, were prepared for potting. End sockets were potted on both ends of four of the cables using the Epon epoxy system. Two cables had end sockets potted with zinc. These cables will undergo impact testing at loads and rates that match a fleet operational envirnoment.

Project Leader: Dr. Tim Eden

High Energy Processing

The High Energy Processing thrust is a leading research and development activity focused on electron beam-physical vapor deposition (EB-PVD) and laser materials processing. Facilities include a world-class laser applications laboratory as well as a unique EB-PVD machine, capable of depositing a variety of industrial-quality coatings at rates up to 15 kilograms per hour.

Unique Capability

Electron Beam-Physical Vapor Deposition (EB-PVD) offers many desirable characteristics, such as relatively high deposition rates (100–150 micron/ minute with an evaporation rate of 10–15 Kg/hr, dense coatings), precise composition control, columnar and polycrystalline, low contaminate, and high thermal efficiency. ARL Penn State has three EB-PVD research units, including a pilot plant coating facility.

Tool Coating

Several major accomplishments have been achieved within the past year in the development of hard carbide and boride coatings synthesized by ion beam assisted, electron beam physical vapor deposition (IBA, EB-PVD). The hardness of titanium carbide (TiC) coatings produced by reactive IBA, EB-PVD was increased up to 3500 VHN. This 15 % hardness improvement is largely attributed to the addition of an ion beam which was used to densify and texture the coating microstructure. TiC coating is commonly used as the bond coat for a subsequent TiB2 coating on WC-Co cutting inserts. TiB2 cannot be directly deposited on to the inserts as it reacts forming an unstable compound. In addition, the adhesion of various coatings deposited by IBA, EB-PVD has been increased from ~5-10 N to over 50 N; the average adhesion value for most PVD coatings is approximately 40 N. Applying multilayered coatings of TiC/TiB2 and Cr3C2/TiB2 can further increase hardness of the coatings. Also, titanium carbide was successfully deposited by the co-evaporation of titanium and carbon through a molten slug of tungsten. Lastly, significant progress has been made in the formation of a super hard, metastable TiBCN coating by the co-evaporation of three ingots: titanium, carbon through molten tungsten, and TiB2 and simultaneously bombarding the surface with a mixture of ionized nitrogen and argon gas.

The adhesion of the TiBCN coating is >50N and has the hardness equal to a soft diamond-like coating. An integral part of this project is transferring this technology to at least one tool company-at no cost to the project. Coated samples are being evaluated by Portsmouth Naval Shipyard (the sponsor) and interested leading tool manufactures (Valenite Co., Richter Precision Inc., and Kennametal Inc.).

Project Leaders: Dr. Jogender Singh and Dr. Douglas Wolfe

Laser Processing Technologies

Technology Leader: Dr. Rich Martukanitz

Mission

To develop new manufacturing processes which capitalize on the unique features of high energy processing technologies and to transfer them to both Navy and industrial centers to immediately benefit the Navy's evolving requirements for fleet readiness at the lowest possible life-cycle cost.

The research conducted is broad in scope, ranging from applied process and materials development through systems integration and technology transfer. Many programs begin as feasibility studies or demonstrations and then successfully evolve into programs for implementing the technology.

This division also continues to interact with industry through its laser processing consortium and sponsored research programs. Its success in developing and implementing laser processing technology may be traced to its balance of applied programs, basic research, and educational initiatives.

Torpedo Repair

Two programs, Repair and Refurbishment of Fatigue Limited Structures and Surface Removal by Fiber-Optically Delivered Lasers, were combined to form the Torpedo Repair program. Torpedoes are routinely fired in an exercise configuration to train sailors and to test the effectiveness of the system. After exercise firing, the torpedo is retrieved, refueled, and returned to service. However, as a result of this testing, the components in the system are often damaged due to operation, handling, and immersion in a seawater environment. These damaged components must be repaired or refurbished in order to maintain the high performance capabilities of the torpedo system. The repair methods currently used for the components have limitations, including the fact that the repairs are non-structural and frequently need to be reapplied at each repair cycle. As part of the repair process, the paint and anodized coating applied to the aluminum component must be removed.

Laser cladding was demonstrated as a method for providing a permanent structural repair on a number of aluminum alloys, including alloys generally considered unweldable by conventional methods. After the initial demonstration, specimens representing observed defects were repaired and tested, the results showing excellent bonding, a small heat affected zone, and adequate mechanical properties. The process was transferred during the course of the project to the Naval Undersea Warfare Center (NUWC) - Keyport Division. After the laser and workcell were operational, personnel at NUWC-Keyport began to develop the laser cladding process on-site, quickly demonstrating satisfactory laser clads on aluminum. Metallurgical analysis samples produced at Keyport were evaluated at ARL-Penn State to determine the quality of the clads and to provide suggestions for process improvements. After the process at Keyport had been optimized, repairs on actual components were initiated. To date a large number of components, many of which had been destined for scrap, have been repaired, successfully tested, and returned to fleet use. To date over $700K worth of assets have been removed from scrap and returned to service. Additional work will continue at ARL to improve the laser cladding process and to perform testing to aid in qualification of the process to meet Navy requirements.

Laser based coating removal offers advantages over the current repair process and is an excellent complement to the laser cladding process. Hard, damage-resistant coatings are used to protect the aluminum surface from the corrosive action of seawater. If damage occurs to the component, the current repair process removes all of the paint and anodized coating on component. After the repairs to the aluminum are made, the component is re-anodized and re-painted. There are two problems with those processes. The removal of the anodized coating is performed by chemical means and a small amount of aluminum is lost from the surface of the component. In addition, the anodize process converts some of the aluminum from the component into the coating, resulting in loss of material during each cycle. The powder epoxy paint system, used to protect the outer surface, employs a high temperature oven to attach and cure the coating. The curing temperature for the paint is within the region of aging temperatures for aluminum alloys. Each heating cycle thereby reduces the mechanical properties of the alloy. Use of laser based coating removal allows for the local removal of both the powder epoxy paint and anodize coating without damaging the surface of the material. A system will soon be in place at NUWC-Keyport to perform coatings removal. ARL will aid in setup of the system and will transfer the developed technology for use on torpedo components. ARL will perform additional testing and process improvements to aid in qualification of the process.

An additional phase is also planned to develop a method to locally apply and cure the paint over the repaired area. The anodized coating can be selectively applied over an area, but a method for selective powder epoxy paint application has yet to be developed. It is hoped that a method for localized curing can be developed using a laser. Development of such a method would allow for a full integrated process to make permanent structural repairs on torpedo components and provide a method to protect the components from additional damage.

Project Leaders: Ken Meinert and Ted Reutzel

Unique Capability

Laser-Aided Processing of Materials offers leading-edge advancements in precision high-speed or deep penetration welding operations with low cladding, cutting, drilling, heat-treatment, glazing, and free-forming component distortion. ARL Penn State has one of the country's largest high-power laser applications development programs in support of industry and the Department of Defense.

Laser Cladding as an Alternative to Chromium Plating for Ground Combat Vehicles

Recent environmental regulations have reduced the use of chromium electroplating. The Marine Corps commonly uses chromium electroplating for wear, corrosion, and dimensional restoration on a wide variety of components including ground combat and combat service support vehicles, as well as aircraft parts. Alternative coating materials and methods must be identified or developed to replace chromium electroplating. Replacement technologies must be cost-effective and meet demanding performance requirements imposed by challenging operational conditions. Further, replacement of chromium electroplating provides an opportunity for the Marine Corps to identify repair processes that actually expand the number of repairable parts. For example, laser cladding, which can deposit material much thicker than chromium plating, can be used to repair components that have dimensional restoration limit requirements.

The investigation of alternative technologies to chromium plating has been taking place in industry. Most notable is the use of laser cladding as a chromium plate replacement by heavy vehicle original equipment manufacturers. Components such as shafts and struts have been successfully repaired using laser-cladding techniques. This technique is now an industry-approved repair process/method. The primary focus of this program is suspension and drive train components found in the Marine Corps' LAV and AAAV-type vehicles. The program is also applicable to heavy combat service support trucks. Components used in Marine Corps vehicles often differ in composition from similar commercial or Army variants due to unique high-stress corrosive operating environments. The adaptation of laser cladding technology to Marine Corps vehicles will provide a cost-effective chromium plate alternative that provides the potential to increase the number of refurbishable components.

The program has developed a laser-clad repair for the propulsion shafts on the AAV. The shaft drives the water pump that propels the vehicle during its amphibious mode. iMAST identified a suitable repair material, developed the laser deposition process, established a post-clad heat treatment schedule, and provided vendor-supplied quotations for production work. Two shafts were repaired at iMAST and delivered to MCLB Albany. The shafts were inspected and found to be free of defects. The parts are now scheduled for field testing during FY 2001.

Project Leader: Eric Whitney

Laser Processing of Nickel Aluminum Bronze

The goal of this project is to decrease the fabrication, repair, and refurbishment costs of nickel aluminum bronze (NAB) components and improve performance through laser materials processing technology. Laser materials processing of NAB offer many advantages over conventional processing technologies. Laser welding and cladding are low heat input processes when compared to arc-welding processes. Low heat input leads to reduced distortion, thereby meeting stringent tolerance requirement and reducing post-weld machining requirements. High material deposition rates can be achieved through laser processing, allowing for reductions in processing time. The performance of laser deposited NAB (both laser clad and laser welded) has been shown to equal or exceed that of conventionally arc-welded material.

This processing technology is being implemented at Norfolk Naval Shipyard's Naval Foundry and Propeller Center through the recent development, integration, and procurement of a robot Nd:YAG laser welding system. Process development for laser beam welding of marine components has been utilized to drive the design of this system. The robotic welding system, scheduled for delivery in the first quarter of 2000, will represent the most advanced Nd:YAG laser welding system to date.

Project Leader: Ken Meinert

Nd:YAG Laser Repair of Aircraft Carrier Catapult Trough Covers Track Wear Surface

Catapult trough covers on aircraft carriers require substantial refurbishment due to the severe operating environment typically encountered. There are four catapults/carrier, with approximately 100 trough covers per catapult. The channel shaped area of the trough covers provides a rolling/bearing surface for the launch shuttle to roll as it accelerates the aircraft from zero to 160 mph in three seconds. The base material of the channel is a high yield carbon steel (HY-100) and operates in a harsh environment of mixed salt water spray and air at elevated temperatures. This combination causes corrosion products to form on the wear surfaces which act as an abrasive causing accelerated wear of the wheel and track surfaces. When the track surfaces wear beyond tolerances (.050 inches), they are replaced with new trough covers. The worn trough covers are unable to be weld-repaired by existing welding processes due to excessive distortion caused by the welding. On the other hand, the low heat input of laser processing enables the channels to be resurfaced with clad metal. New cost is approximately $25K/trough cover, but laser cladding can be done for less than $10K per cover. It is estimated that 400 covers per year will need repaired during the course of several more years. Laser cladding can generate a savings of approximately $6M per year.

This ManTech program will expand the application of Navy developed Nd:YAG laser weld repair technology to the repair of worn surfaces with a superior, longer lasting corrosion and wear resistant material and transition this program onto the production floor.

Project Leader: Dr. Rich Martukanitz

Advanced Composites Technologies

Technology Leader: Dr. Kevin Koudela

Mission

To conduct applied research on advanced materials and structures for marine applications with emphasis on acoustics, reliability, affordability, and technology transfer.The benefits of advanced composites include weight savings of 25–50% over conventional materials, acoustic signature reduction, and corrosion resistance.

Challenges

The challenge of composites is that it must address traditional design requirements relative to strength/ stiffness as well as hydrodynamic and acoustics. Additionally, it must also address unique requirements pertaining to environmental effects, fatigue and impact, attachments/joints, and manufacturability and inspectability.

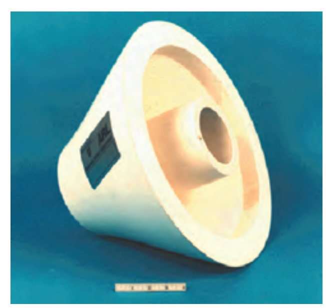
Advanced SEAL Delivery System

This project is providing materials and process engineering support to include design certification test support. During the fiscal year new composite material was identified for the nose and aft shell stiffeners. Composite material systems were qualified on hull number one. C-bar and J-bar attachments brackets designs were qualified via supplemental tests.

Project Leader: Eric Strauch

Unique Capability
Marine Composites offer the potential for significant weight reductions, a decrease in life-cycle costs, and signature reductions. ARL Penn State has a complete composite design, prototype fabrication and testing facilities in-house as well as an extensive network of proven subcontractors. Capabilities include acoustically tailored composite structures, processing and characterization of thick section composites, low-cost fabrication techniques, and life qualification for composites.

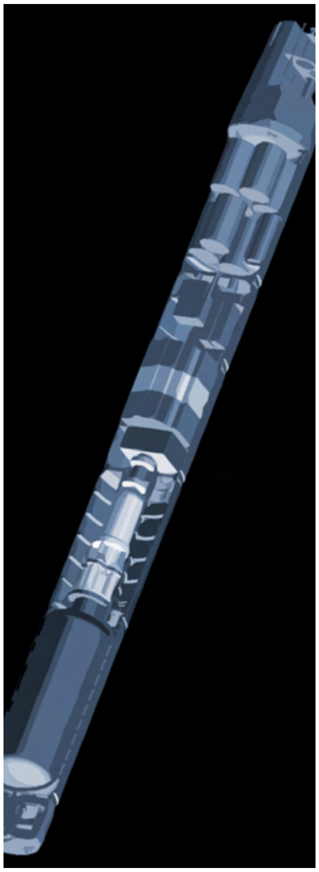
Current efforts within the Advanced Composites division relative to Navy and Marine Corps issues include: naval platform programs, torpedo programs, acoustic control, advanced material life prediction, and protective coatings.



Manufacturing Systems

Technology Leader: Dr. Mark T. Traband

Misson

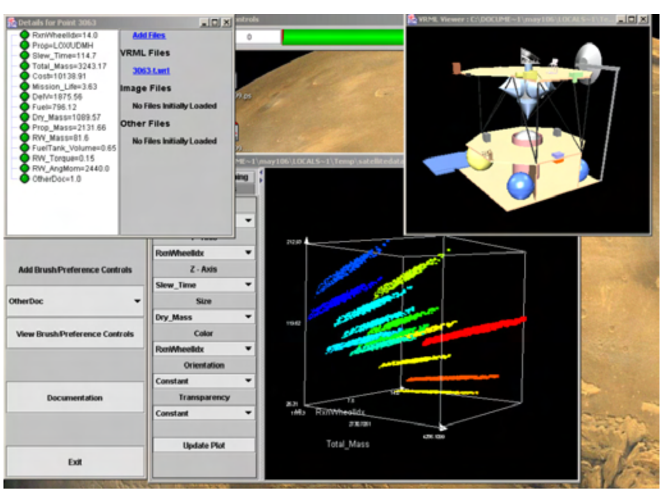


To perform research, advanced development, and implementation in design and manufacturing systems, through the integration of information technology and product and process design. Historically, the development of manufacturing systems has been decoupled from the process of design. A major focus of current research is therefore in developing methodologies to automate and/or more tightly integrate the design process, cost estimating, and manufacturing system design. Virtual prototyping of component and manufacturing system designs enables engineers to explore a much larger set of design options, resulting in more robust designs, with shortened leadtimes, and reduced lifecycle cost.

Unique Capability
Rapid design space exploration for both product and process design, if performed early in the lifecycle of a product, can result in tremendous downstream benefits in both performance increases and cost reduction. By increasing the number of options considered, a more robust design and associated manufacturing process can result. ARL combines Trade Space Exploration, multidisciplinary design pptimization, advanced visualization tools, and process simulation to achieve the robust product and process designs.

Trade Space Exploration

The Trade Space Exploration (TSE) method, developed at ARL with ONR support, is derived from Balling's design by shopping paradigm, and it allows a decision-maker to first explore the design space and then choose an optimal design from a set of possible designs. The TSE method can be divided into three primary steps: model building, experimentation, and exploration. The model building step creates a system model by coupling subsystem models into a constrained system that can be used to generate many potential designs. The experimentation step selects the values of inputs used to generate the range of feasible designs to be created in the model building step. The last step is the exploration of the resulting set of designs to look for known trends as a form of validation of the models and to act as a decision-making tool. Key to this step is presenting large amounts of information in an easy to understand way.



ARL Trade Space Visualizer being used to explore satellite conceptual designs

The ARL Trade Space Visualizer (ATSV) is a multi-dimensional visualization tool that is used to explore the relationships captured in the design data. It has the ability to explore multi-dimensional data, dynamically apply constraints and preferences, determine sensitivities for a selected design, and visualize design uncertainty.

TECHNOLOGY APPLICATION:
ARL has developed a Trade Space Exploration for satellites that uses the ASTV. The system has the capability to generate design concepts (virtual prototypes) for spacecraft. Virtual prototypes consist of the design data necessary to form high-level parametric cost estimates, design data necessary to ensure satisfaction of system requirements and compatibility between subsystems, and geometric data sufficient to show relative sizing and placement of subsystem components.

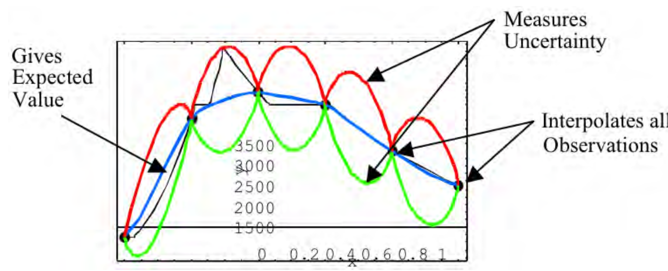
Metamodeling

The design by shopping paradigm has proven to be very useful to decision-makers in understanding the possible trades available to them, giving them evidence to support their decision of a final design. One difficulty with the paradigm is it requires a significant number of model evaluations. Metamodels, models of models, are low fidelity models used as computationally efficient surrogates of the original subsystem analyses, a high fidelity model (HFM). Kriging models are used as metamodels in the TSE method because they can interpolate a set of observations of an HFM. Additionally, since a kriging model is a probabilistic model, it can quantify the uncertainty associated with the model.

Current research is developing methods to quantify uncertainty and risk in design by using the probabilistic nature of the kriging model. These methods will use Monte Carlo simulations, varying the input uncertainties to a potential design, to quantify the resulting performance uncertainty. Additionally it will perform a sensitivity analysis that will identify the sources of performance uncertainty, including model uncertainty. The results of this uncertainty analysis can be used to improve the model uncertainty by including additional information near the design of interest.

TECHNOLOGY APPLICATION:

Current multi-layered, multi-functional material structures rely heavily on combination solutions. In essence, dedicated layers are incorporated that meet requirements associated with particular aspects of a defined threat while providing little or no utility in performing the other various functions. For instance, armor solutions are often parasitic from a structural load bearing perspective. ARL is working on an optimization scheme for multi-layered systems that includes the development of an in-depth understanding of interface characteristics. The optimization of these complex materials will require the use of extremely complex analysis codes that can be applied at various levels and length scales pertinent to new platform implementations. Using metamodels for the complex codes will enable a much broader range of the design trade space to be evaluated, ensuring the development of more optimal multi-functional materials.

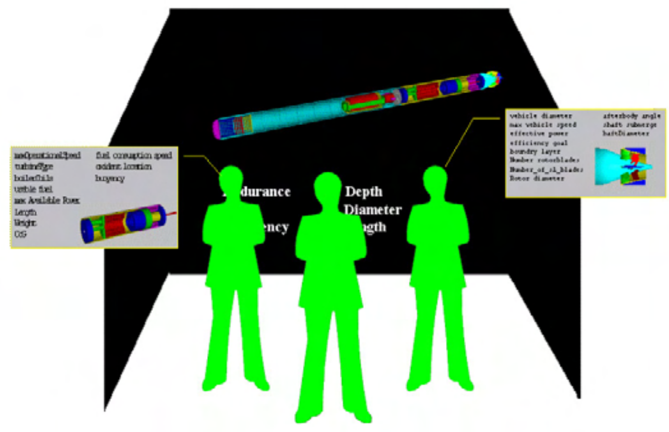


Kriging Model – A Spatial Stochastic Model

Virtual Design Environments

The next generation of system engineers and decision makers want to explore the possible limits of a design space quickly. ARL Penn State has developed a virtual conceptual design environment to allow the engineer to virtually explore design trade-offs and the complex design space of an engineering product. The system generates virtual prototype models in a CAVE-like environment that meet a set of user specified requirements and technology options. The user can navigate around the model and interact with the model directly through voice and gesture recognition. The user may vary mission and design requirements and the model will change its form dynamically to meet the new specifications. In addition to this capability the user can visualize the complex function space of the model and interact with the visualization. A complex function space often involves higher dimensional data sets. In the immersive environment users will be able to view projections of higher dimensional data onto three-dimensional space, and choose points in the function space to select designs for further analysis. After they choose a point in the function space the virtual prototype will transform to represent the selected design point.

Current research work is focused on the designer's need for quick data access and customized data views in a virtual environment. This work extends the current virtual environment into a multi-user, multi-discipline design tool. The new environment will allow engineers to collectively view how design parameter changes affect subsystems as well as overall weapon characteristics. A unique innovation of this proposed work is that the environment will provide individually customized data views to each of the subsystem experts as well as system level data sharing for all participants.



Immersive Environment

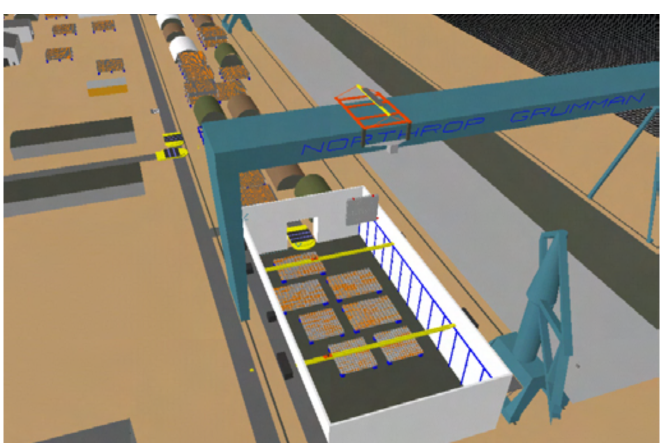
TECHNOLOGY APPLICATION:
ARL has developed a Virtual Design Environment for a 6.25" torpedo, or Anti-Torpedo Torpedo. In this environment the user is presented with a virtual weapon design. They interact with the weapon through voice commands and gesture recognition. For example they modify a design requirement, such as the torpedo's endurance, by raising and lowering their hands. The virtual torpedo will dynamically change shape and topology to meet the new design requirements. Through voice commands the user requests to see a detailed view of the array configuration or view the array beam formation. This environment provides a real time visual interface between the weapon design space and the weapon physical features.

Manufacturing Process Simulation

Closing the loop between product design and manufacturing process design enables engineers to rapidly assess the impact that design changes have on process sequences, product flow, and manufacturing leadtimes. A useful method for manufacturing process design is discrete event simulation modeling. These tools enable:

- Assessment of proposed manufacturing facilities prior to capitalization, to include visualization of the facility, material handling, process bottlenecks, part routing, and worker and machine utilizations,
- Analysis of the impact of new work on an existing facility, and
- Evaluation of alternative dispatching rules or production schedules in an existing facility.

ARL has teams of analysts and model builders experienced in several different simulation modeling languages. Typical tasks in a project go beyond simply build a model and may include data collection, distribution fitting, verification and validation, and output analysis. In addition, basic simulation modeling capabilities are often extended through the use of immersive visualization, web access to remote models, custom UI's, and database/Excel integration.



Simulation Model of the Final Assembly Platen at Northrop Grumman Newport News

TECHNOLOGY APPLICATION:
In an effort to reduce or eliminate production delays due to weather and time spent to setup and tear down temporary shelters, Northrop Grumman Newport News (NGNN) is investing in a Covered Modular Outfit Facility (CMOF), a climate controlled facility that will provide cover for about 20% of the Final Assembly Platen, the construction area that is spanned by the large dry dock crane. The CMOF will be primarily used for structural construction and outfitting for high-value-added products for CVN 21. Under ONR sponsorship, ARL is building a detailed discrete event model of the CMOF and the nearby fabrication facilities. This model will provide analytical proof that the new building will provide the expected productivity improvements, and will enable NGNN to optimize the operations and sequence of scheduled work in the new facility.

Integrated Data Environments

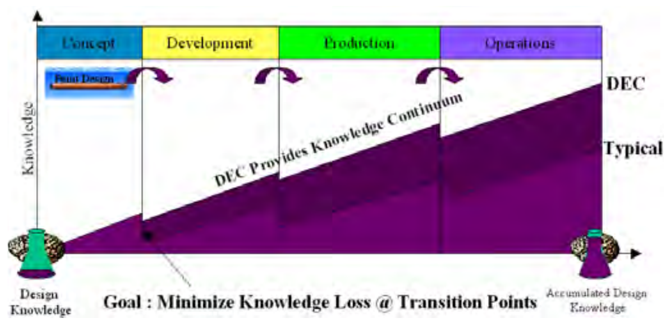
The product development lifecycle for any weapons system begins with the definition and capture of customer requirements and proceeds through product design and tradeoffs, analysis and simulation, development of manufacturing processes, testing, and product support. The evolution of a product through these phases involves many transitions of data through the organizations involved with these processes. A significant amount of technology and data may be lost during these transitions, resulting in significant reinvention costs. In many organizations, engineering information is not well managed, and may be scattered throughout the organization in a variety of unconnected databases, computers, and notebooks. Often, data is duplicated in several locations, leading to confusion about which data is the most current.

The use of integrated data environments (IDE's) is a strategy for providing access to product and process information electronically, and moving that data (which may include CAD models, results of simulations and analyses, cost estimations, and testing data) through its lifecycle. IDE's typically span many parts of and organization, connecting users through a network (increasingly, via the internet) to electronic representations of product information.

One class of software that is often used to manage product-related data in an IDE is known as Product Data Management (PDM). PDM systems manage all forms of data throughout a product's life cycle, including information such as 2-D drawings, 3-D models, tooling programs, specifications, design analyses and hard copy documents to cite a few examples. PDM systems do not create product data as do CAD systems, but manage the files once created.

TECHNOLOGY APPLICATION:

With the emphasis on cost effective commercial, off the shelf solutions to facilitate the functional and data needs of the Navy's Surface Ship Torpedo Defense (SSTD) program, ARL has created the Distributed Engineering Center (DEC) to manage the program's data throughout the weapon systems' lifecycle. ARL performed a requirements analysis and evaluated the commercial PDM solutions available; these requirements were based on DOD acquisition guidelines, other acquisition programs best practice, and the SSTD and NAVSEA design agent requirements. A number of best-of-class PDM systems were evaluated by ARL to determine which met the requirements of cost, functionality, and capability. ARL installed and configured the software to provide control of unclassified documentation and product data, and to allow collaboration between users across many Navy and contractor organizations. Future plans call for the installation of a separate classified PDM system with access via an encrypted network.



Retention of Design Knowledge Using an IDE

Complex Systems Monitoring

Technology Leader: Dr. Karl Reichard

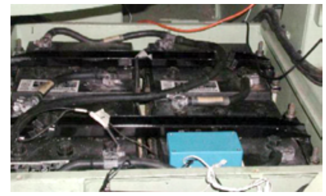
Mission

The Complex Systems Monitoring and Automation Department develops, demonstrates, inserts and transfers new technologies to monitor and control the health and operation of mechanical, electrical, and electrochemical systems to DoD, other government and industrial customers. The Complex Systems Monitoring and Automation Department applies a systems engineering approach to analyzing customer problems, then identifies applicable technologies and formulates an engineering implementation to solve the problem. Where applicable technologies are not available, department personnel develop new fundamental science and technology, with the same end goal of technology insertion and transfer.

The Complex Systems Monitoring and Automation and Applied Enterprise Systems Departments comprise the Systems Operations and Automation Division. Together, we develop solutions that implement a continuous information thread for complex systems from sensor data through actionable information in a commercial Enterprise Resource Planning system. The departments are currently working to assist the Marine Corps and U.S. Army in exploring the automation of information insertion for the transformation of logistics and support systems.

Complex system monitoring applies sensors to collect data from subsystems and components, analyzes the data to extract knowledge, applies automated reasoning to interpret data for the user, and estimates the health and performance of the system to track system degradation. Traditional and intelligent control systems are applied to control performance, reduce noise and vibration, and to automate manned, man-in-the-loop and fully autonomous systems. The department has worked on technology development, insertion and transfer projects for system monitoring and automation for a number of DoD platforms including JSF, the Marine Corps Expeditionary Fighting Vehicle, the Marine Corps Light Armored Vehicle, DDX, DDG and CG-class warships, and the Army's HEMTT truck.

Battery diagnostics and prognostics



Complex System Monitoring and Automation personnel have developed battery health monitoring technology capable of fast, reliable predictions of battery state of charge, state of health, and state of life with performance errors <5%. The system uses a patented ARL design for measuring critical internal battery parameters and ARL developed algorithms for determining state of charge, state of health and state of life. The state of charge measurement provides a measure of current capability with greater accuracy than traditional voltage and current measurements. The state of health provides an accurate assessment of the degradation modes affecting remaining useful life for the battery and state of life provides an assessment of remaining charge cycles. Together, the state of health and state of life measurements provide real prognostic health information. The battery health monitoring system can be embedded in a battery, charging system, or the vehicle electrical system and communicates battery prognostic information over an OSA-CBM compliant interface.

Project Leader: Dr. Karl Reichard

Repair Technology

Technology Leader: Mr. Sean Krieger

Powered by the Office of Naval Research Manufacturing Technology (MANTECH) program, Repair Technology (REPTECH) is the Navy's only Center of Excellence dedicated to improve Navy and Marine Corps depot repair and maintenance capabilities. REPTECH applies appropriate technologies to improve capabilities of the remanufacture and repair community and plays a central role in discovering and utilizing emerging technologies for the Navy. Because lifetimes of the Navy and Marine Corps' assets are increasing — sometimes beyond their designed life — Repair Technology investments are needed to close gaps between the current capability of the repair depots and the sustainment needs of the weapon system. REPTECH reduces the depot, shipyard or logistic base's risk to schedule, costs, and performance of repairing the fleets weapon systems by answering the business decision questions.

iMAST has been designated by the Navy as the resident coordinating center for its Repair Technology program.

Charter

- Apply emerging technologies to improve the capabilities of the repair community
- Improve repair processes and the affordability of repair facilities
- Execute S&T projects which directly affect depot-level maintenance
- Projects are executed under the direction of the REPTECH Working Group
- Communicate by all means available
- Reduce duplication of effort in REPTECH related R&D
- Leverage program funding with funds from other programs and agencies

Management Structure

The REPTECH Working Group (RWG) is a Navy system's command management level team that oversees all REPTECH projects. It consists of one technology integration management representative from NAVSEA, NAVAIR, MARCOR, NAVSUP, and SPAWAR with an ONR MANTECH Program Officer (ONR 361) as the RWG chair. The RWG meets semi-annually to review all current projects as well as discuss new potential efforts. RWG was created to develop a coordinated approach to executing and identifying REPTECH needs for the Navy and Marine Corps.

HAZMAT Analyzers for Rapid on-Site Analysis

Reduce costs and time associated with the analysis of hazardous materials in coatings on naval vessels.

Customer: Pearl Harbor Naval Shipyard
NAVSEASYSCOM
Portsmouth Naval Shipyard
Norfolk Naval Shipyard
Puget Sound Naval Shipyard

Solution: Develop a portable or hand-held analyzer to rapidly determine PCB, Pb, and Chromate levels in various surface coatings on naval vessels.

Benefits:
- Reduce labor and analytical costs
- Reduce analytical time, decision making and planning times
- Improve remediation process cycle times

POC: ***Janice Keay***

Helicopter Blade Refurbishment

Reduce costs, improve quality, eliminate human error, and increase capability for Helicopter Blade paint removal processes.

Customer: NADEP Cherry Point
NAVAIRSYSCOM
Sikorsky Aircraft

Solution: Develop a repeatable, quality, cost-effective Helicopter Blade paint removal process for CH-53, Ch-46D/E, and CH-60 helicopters. Process selected is ND:YAG laser paint stripping solution.

Benefits:
- Reduce labor from 20 hours to 4 – net cost-avoidance $180K/year
- Improve artisan quality of life – current process is labor intensive
- Reduce worker health safety risk
- Reduce damage to substrate
- Improve processing capability

POC: Ted Reutzel

Polycan Fabrication

The current fabrication process for polycans is mostly manual and labor intensive. Each layer of poly is custom fit with tight tolerances. Innacuracies can cause slight variation in the complete can. Both the forming process and distortions during the fit up and welding processes cause these inaccuracies in assembly.

The Polycan process is on the critical path for overhauling/refueling US Navy submarines.

Customer: Portsmouth Naval Shipyard
Pearl Harbor Naval Shipyard
NAVSEASYSCOM

Solution: Reduce lead time for Polycan fabrication. Develop parametric CAD models of all cans, automate CMM programming for can cavity profiles, automate reverse engineering can cavity profiles, and improve machining and waterjet-cutting processes of polycans.

Benefits:
- Eliminate Polycan production from critical path
- Reduce production costs
- Reduce lifecycle costs
- Improve scheduling of polycan production

POC: Paul Swanson and Mark Traband

Submarine Vertical Launch System Tube Repair

Develop a method to more efficiently repair US Navy Submarine Vertical Launch System (VLS) Tubes by implementing a laser cladding techniques.

Customer: COMSUBPAC
NAVSEASYSCOM
Pearl Harbor Naval Shipyard
Puget Sound Naval Shipyard
Norfolk Naval Shipyard
Portsmouth Naval Shipyard

Solution: Determine root cause of corrosion damage in VLS tubes. Develop, test and implement a convertible motion device to laser clad and re-dimension the affected tube to original specifications.

Benefits:
- Reduce life cycle costs of tube
- Increase fleet readiness
- Reduce VLS tube repair time
- Decrease or eliminate future corrosion in tube
- Improved depot personnel quality of life

POC: Eric Whitney

M198 Howitzer Mechanism Tester

Implement a Howitzer recoil mechanism testing system that will reduce costs, improve logistics, and shrink the rebuild schedule for the USMC Barstow, CA, depot. The current testing procedure is inconsistent in quality and creates a bottleneck on the depot's schedule.

Customer: USMC Maintenance Directorate
USMC Logistics Base Barstow
USMC Logistics Base Albany

Solution: By bringing the recoil testing in-house and designing the system to include both the M198 and M777 Howitzers, as well as potentially the M1A1, the depot will reduce costs to repair and turn-around USMC assets needed in the War.

Benefits:
- Lower test costs
- Less testing time
- Streamlining of test scheduling
- Safer and less rigorous conditions for test personnel
- On-site test facility which can be used as a diagnostics tool
- Less environmental impact due to testing
- Fewer personnel required for testing

POC: Sean Krieger

CH-46 Gear Repair

Due to operations, the Naval Aviation Depot at Cherry Point (NADEP CP), NC, scraps over $1M worth of transmission gears a year during overhaul of CH-46 aircraft. ARL REPTECH has uncovered a super finishing process that can remove the surface damaged layers of the gear tooth while maintaining metallurgical and dimentional quality of the gear. If the strength and durability of the gear can be demonstrated to be comparable to "new" gears then scrap gears can be reused. Further, the improved surface finish of the repaired gears will result in extended service life and reduced heat generation in the gear mesh.

Customer: NADEP Cherry Point
NAVAIRSYSCOM
Boeing Aircraft

Solution: Demonstrate gear strength and durability and implement the REM Superfinishing process at NADEP CP for the CH-46 Sun Gears that will reduce scrap, improve wear resistance and reduce heat losses in the transmission.

Benefits:
- Reduced gear procurement costs
- Improved surface quality of repaired gears will provide extended service life
- Improved surface quality of repaired gears will reduce heat losses in the gear mesh
- Since new gears are a long-lead item, availability of repaired gears would impact aircraft overhaul time

POC: Suren Rao

Submarine Alignments and Inspections

The inspections and alignments required on submarines during naval depot availabilities are difficult, time consuming, and costly. This project will review three inspection/alignment tasls required on 688 Submarines in the sail, torpedo tube, and steering/dive plane areas. The project is to implement new cost-effective inspection technologies to improve the current inspection and alignment process of the three selected areas.

Customer: NAVSEASYSCOM
Portsmouth Naval Shipyard
Norfolk Naval Shipyard
Puget Sound Naval Shipyard and Intermediate Maintenance Activity
Pearl Harbor Naval Shipyard and Intermediate Maintenance Activity

Solution: Using the standard engineering approach, ARL REPTECH will evaluate and/or develop the necessary inspection and alignment techniques to reduce the costs of this job for the depot as well as improve the user-friendliness.

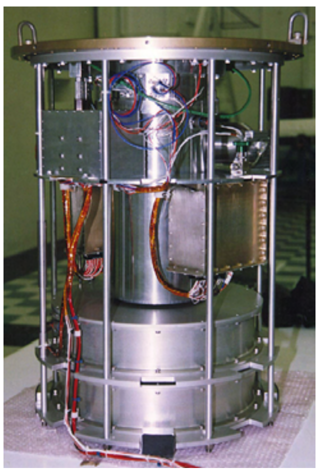
Benefits:
- Captured featured data:
  - Provides electronic records for archival
  - Validates/Invalidates alignment
  - Encourages statistical analysis
  - Provides Reverse Engineering capability
- Reduced downtime
- Increased reliability
- Fewer repair costs
- Increased flexibility

POC: Sean Krieger

Technology Insertion Opportunities for Navy ManTech

The iMAST technologies listed below are available for application within the Navy ManTech Program. Sponsorship, however, is required from a Naval Systems Command (SYSCOM) in order to initiate a program. For more information on the technology, contact the project leader noted. For more information on how to initiate Navy ManTech projects, contact your respective SYSCOM ManTech representative.
Each year, technology "issues" are entered into a database by respective systems commands. These issues are then reviewed and prioritized by a Navy ManTech executive steering committee. The committee selects appropriate projects within an established funding range to support Navy and Marine Corps fleet requirements.

Thermoacoustic Refrigeration



ARL Penn State is developing a thermoacoustic chiller (TRITON) with a 3-ton cooling capacity (10 kW) for shipboard application under ONR's Environmental Requirements Advanced Technology (ERAT) Program. The cooling produced by the unit is created by a standing acoustic wave that expands and compresses inert gas within a porous plastic medium called a stack. Heat exchangers on each side of the stack carry away waste heat on one side and chilled water on the other side.

The acoustic wave is developed by a high-efficiency linear electric motor operating like a large loudspeaker. There are no HFCs or CFCs involved in creating the cooling. In addition, there are no sliding seals or other moving parts in the system other than the linear motor. This means no lubrication or maintenance of the chiller is required. To date, a 4-watt thermoacoustic cryocooler has been demonstrated on a Discovery space shuttle mission (STS-42) in 1992, and a 400-watt system was operated for a week to cool radar electronics on the USS *Deyo* (DD-989) in 1995. The TRITON 10 kW unit will be demonstrated at a land-based test site in during late year 2000. If successful, it will undergo sea trials during FY02/03 timeframe. This technology will provide the Navy with an the opportunity for environmentally benign cooling in critical areas as a distributed system rather than a centralized one.

POC: Bob Keolian

Manufacture of Laser-Cut and -Welded Housings for High-Performance Transmission Application

ARL Penn State has demonstrated the feasibility for affordable advanced laser cutting and welding techniques in concert with high-strength materials to produce welded transmission housings that will meet the performance requirements for ground combat vehicles, as well as rotorcraft and VSTOL aircraft employing high-performance transmissions. ARL is capable of establishing cost and performance benefits of a laser cut and welded housings versus conventional cast housings.

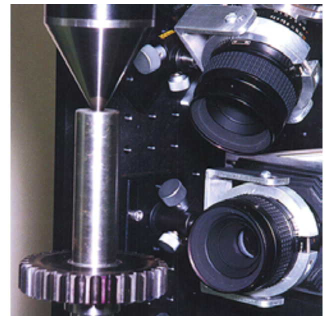
The use of a welded steel structure has a number of advantages and benefits over cast aluminum and magnesium transmission housings. These include comparable production costs with dramatically reduced manufacturing lead times, lower weight designs (permits mini-lube systems), reduced lifecycle costs, high temperature operation, improved heat transfer capability, improved damage tolerance, and field repairability.

POC: Dr. Rich Martukanitz

Noncontact High-Speed Gear Inspection

ARL Penn State has demonstrated the feasibility of developing an economical noncontact high-speed precise gear surface inspection system for DoD depots and gear manufacturers. The benefits of this technology include reduced gear inspection time by a factor of 100, improved gear inspection accuracy via high spatial sampling, enhanced gear production efficiency with potential on-line inspection, and greatly reduced production costs due to increased quality assurance and lower number of false rejects.

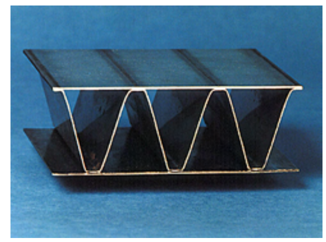
Applications in military and commercial sectors include mechanical drive transmission inspection requirements associated with virtually all motor vehicles, aircraft, and powered marine vehicles, as well as most machine tools, military combat vehicles, industrial robots, and many household appliances.



A previous NIST stamp-of-approval review for the optical measurement technique has prompted increase interest in this technology. Sensor progress includes examination of speckle compensation methods for coherent light sources including a new high-power laser diode with pigtailed fiber optic delivery. Two methods for dynamic reflectivitiy nonuniformity compensation (DRNC) have been developed and fully tested. A compact and rugged mechanical assembly for the optical head has been designed and is being fabricated.

POC: Dr. Karl Reichard and Dr. William Mark

LASCOR: Lightweight Structural Panels



ARL Penn State has developed a laser-welded corrugated (LASCOR) metal paneling process which provides a stiffness and strength comparable to conventional steel plate, but at greatly reduced weight. LASCOR has demonstrated its durability by showing favorable resistance to fire, blast, ballistic impacts. LASCOR can be manufactured in a variety of configurations and used with different alloys for customized properties.

These properties make it a strong competitor for conventional structural steel panels wherever weight reduction is a concern. Application has been made within the top sail structure of the USS *Mount Whitney* where approximate weight was reduced by 10,000 pounds.

POC: Ted Reutzel

Pericyclic Transmission

The need for an advanced, high-efficiency variable rotor speed main transmission system that features split torque, split path, reduced-parts, and pure rolling contact power transfer via kinematic/kinetic pericyclic technology is being addressed by ARL Penn State. Current planetary and bull gear main transmission drives are fixed ratio systems that preclude changing rotor speed. The basic architecture of planetary and bull gear main transmission drives tend to preclude achievement of a major increase in power-to-weight ratio (SHP/LBs) and reduced cost due to the number of high precision, high-cost, weight components, and their reliability challenges.

The pericyclic variable rotor speed drive has a higher probability to achieve the power density, reliability and cost goals identified for the Joint Transport Rotorcraft and other system upgrades.

POC: Gary Neal

Spray-Formed Aluminum Alloys for High Performance Jet Engine Application

This validated spray-formed high-temperature alloy process is optimized for component manufacturing for jet engine fan and stator vanes. The process is available for evaluation and implementation. Using the unique capabilities of the spray forming equipment resident at ARL Penn State, this process is integrated for engine design and verification efforts.

POC: Tim Eden

Air Vehicle Technology Group

Integration of advanced materials, manufacturing processes, tooling and fixturing will facilitate reduction in life-cycle costs, empty-weight/gross-weight ratio, vibration and interior noise. These efforts will also facilitate increases in payload/gross weight ratio, mission range, survivability, and operational availability. All improvements are made more affordable due to significant reductions in labor and in operating and support (O&S) costs.

Powertrain Technologies

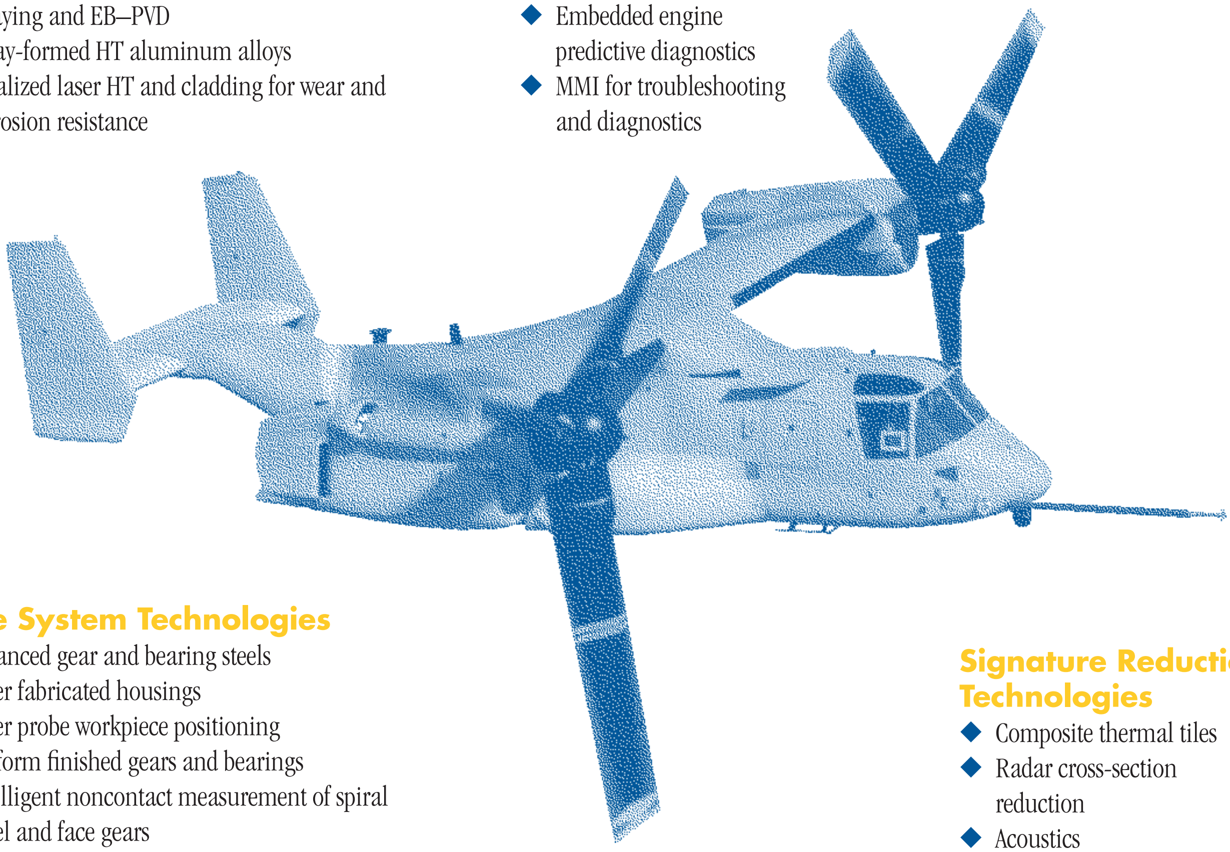
- Performance prediction
- Rapid prototyping
- Drive shaft laser balancing
- Condition monitoring
- Wear-resistant coatings via cold gas dynamic spraying and EB–PVD
- Spray-formed HT aluminum alloys
- Localized laser HT and cladding for wear and corrosion resistance

Health Usage Monitoring System Technologies

- Condition-Based Maintenance
- Distributed diagnostic system architectures
- Embedded engine predictive diagnostics
- MMI for troubleshooting and diagnostics

Rotor System Technologies

- Rotor blade NDI (finds delamination)
- Control of radiated sound power



Drive System Technologies

- Advanced gear and bearing steels
- Laser fabricated housings
- Laser probe workpiece positioning
- Ausform finished gears and bearings
- Intelligent noncontact measurement of spiral bevel and face gears
- Gear noise control
- Design for power density

Airframe System Technologies

- Laser fabricated flooring
- Composite sandwich panels for noise control
- Spray formed HS aluminum alloys
- Protective armor

Other

- Conceptual design trade studies
- Manufacturing process modeling

Repair Technology

- NDI technologies (shearography)
- Coating application and removal
- Component repair methods

CBR Technologies

- Photon-based cleaning of CBR agents
- Laser-based cleaning of CBR agents

Signature Reduction Technologies

- Composite thermal tiles
- Radar cross-section reduction
- Acoustics

Landing Gear System Technologies

- Laser cladding
- Spray formed HS aluminum alloys

Ground Combat and Combat Service Support Vehicle Technology Group

The integration of advanced materials, manufacturing processes, tooling, and fixturing will result in reductions in gross weight, vibration, interior noise, and life-cycle costs as well as increases in mission range, survivability, and operational availability. These improvements are made more affordable due to significant reductions in labor and in operating and support (O&S) costs.

Drive System Technologies

- Advanced gear and bearing steels
- Laser fabricated (cut and welded) housings
- Laser probe workpiece positioning
- Ausform finished gears and bearings
- Intelligent noncontact measurement of spiral bevel and face gears
- Gear noise control
- Design for power density

Health Usage Monitoring System Technologies

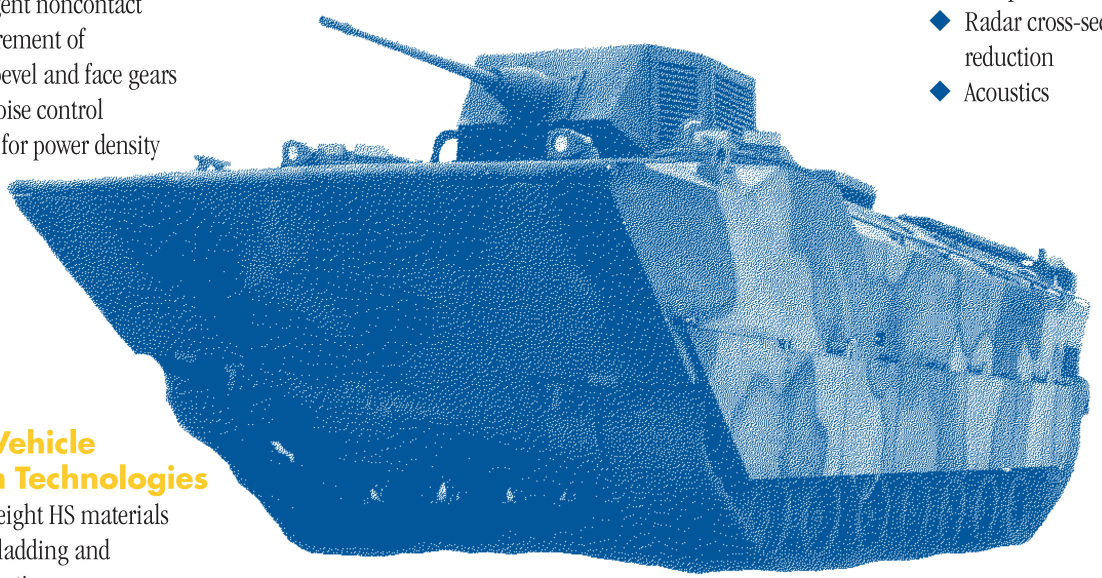
- Condition-Based Maintenance
- Distributed diagnostic system architectures
- Embedded engine predictive diagnostics
- MMI for troubleshooting and diagnosis

CBR Technologies

- Photon-based cleaning of CBR agents
- Laser-based cleaning of CBR agents

Signature Reduction Technologies

- Composite thermal tiles
- Radar cross-section reduction
- Acoustics



Track Vehicle System Technologies

- Lightweight HS materials
- Laser cladding and heat treating

Structural System Technologies

- Armor systems
- Materials and design

Other

- Conceptual design trade studies
- Manufacturing process modeling

Powertrain Technologies

- Performance prediction
- Rapid prototyping
- Drive shaft laser balancing
- Condition monitoring
- Wear-resistant coatings via cold gas dynamic spraying and EB-PVD
- Spray formed HT aluminum alloys
- Localized laser HT and cladding for wear and corrosion resistance

Repair Technology

- NDI technologies (shearography)
- Coating application and removal
- Component repair methods (laser cladding)

Naval Surface Platform Technology Group

The integration of advanced materials, manufacturing processes, tooling and fixturing will result in reductions in gross weight, vibration, interior noise, and life-cycle costs, as well as increases in mission range, survivability, and operational availability. These improvements are made more affordable due to significant reductions in labor and in operating and support (O&S) costs.

Stack Gases Monitoring And Treatment

Dispersed Auxiliary System

- Acoustic refrigeration

Autonomous Ship Systems

- Intelligent control
- Remote sensors
- Condition-Based Maintenance
- Advanced lubricants

Deck and Deckhouse Materials

- LASCOR
- Composite materials
- Non-skid surfaces

Laser Processing

- Welding
- Cutting
- Cladding
- Forming

Propeller

- Design
- Cladding
- Repair
- Materials

Information Technology

- Electronic data transfer
- Intelligent management of documents and data

Rudder/ Appendages

- Coatings
- Materials

Drivetrain Technologies

- Advanced gear materials
- Optimizing tolerances for performance

Other

- Environmental systems
- Lifecycle engineering (REPTECH)
- Wear and corrosion-resistant alloys for structures, valves, and tubing
- Conceptual design trade studies
- Electro-optics
- Paint removal
- Manufacturing process modeling

Naval Sub-Surface Platform Technology Group

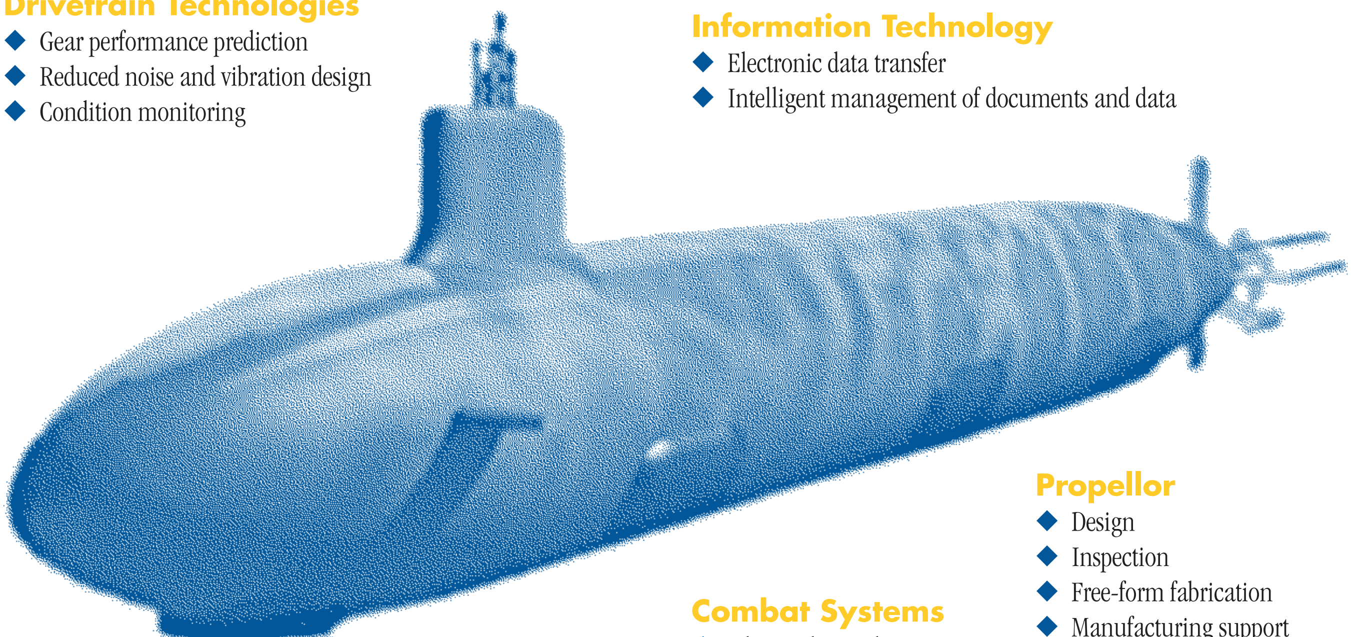
The integration of advanced materials, manufacturing processes, tooling and fixturing will result in reductions in gross weight, vibration, interior noise, and life-cycle costs, as well as increases in mission range, survivability, and operational availability. These improvements are made more affordable due to significant reductions in labor and in operating and support (O&S) costs.

Hull
- Laser forming, welding, and cutting
- Laser cutting, welding, and welding of structural shapes
- Sonar dome fairings
- Improved paint removal and application systems

Drivetrain Technologies
- Gear performance prediction
- Reduced noise and vibration design
- Condition monitoring

Autonomous Ship Systems
- Intelligent control
- Remote sensors
- Condition-Based Maintenance
- Advanced lubricants
- Information systems

Information Technology
- Electronic data transfer
- Intelligent management of documents and data



Propellor
- Design
- Inspection
- Free-form fabrication
- Manufacturing support
- Repair

Combat Systems
- Advanced torpedeo systems
- Anti-torpedeo torpedeo

Other
- Environmental systems
- Lifecycle engineering (RepTech)
- Wear and corrosion-resistant alloys for structures, valves, and tubing
- Conceptual design trade studies
- Manufacturing process modeling

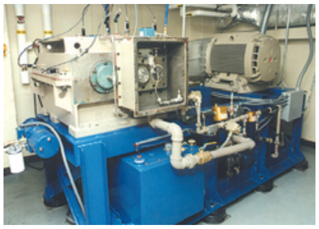
Auxiliary Systems
- Acoustic refrigeration

iMAST Facilities and Equipment

MECHANICAL DRIVE TRANSMISSION

Advanced Manufacturing Facility

- Provides equipment, tooling, processing, and inspection equipment to enhance industrial manufacturing process technology
- Permits affordable gains in component performance
- Reduces life-cycle costs



Drivetrain Performance Testing Facility

- Permits comparative evaluation of new technologies to facilitate implementation
- Develops advanced materials technology databases for high-performance mechanical drive components
- Validates predicted gear performance behavior in terms of vibration/noise characteristics

Gear Dimensional Inspection Facility

- U.S. Navy's Gear Metrology Laboratory
- Only DoD neutral testing site for verifying measurement accuracies related to gear specifications
- 48-hour advance notice capability for emergency gear repairs

Prognostics Development and Testing Facility

- Provides model-based testing and evaluation methods for in-service prediction of remaining useful life in material elements, components, subsystems, systems, and weapon systems platforms.

MATERIALS PROCESSING

Spray Metal Forming

- 5,000 sq. ft. facility
- Full metalography and surface characterization capabilities
- Research scale/pilot plant equipment
  - melts up to 65kg of aluminum
  - produces billets (16" × 10"), strip/plate (12" × 6" × .8"), tubes (12" × 1")
- Capabilities to produce metal matrix composites

High-Velocity Particle Consolidation (HVPC)

- Research scale equipment
- Capability to spray a variety of different materials on numerous substrates

Nanophase Material Facilities

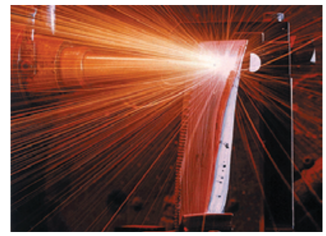
- Nanophase powder consolidation and sintering capabilities

Surface Technologies

- Pin on disc wear testers
- Erosive wear testers
- Reciprocating wear testers
- Seal test rigs
- Controlled-environment test rigs
- Facilities and expertise for lubricant development
- High-pressure hydro-static equipment
- Hot press for powders consolidations and laminated cermics

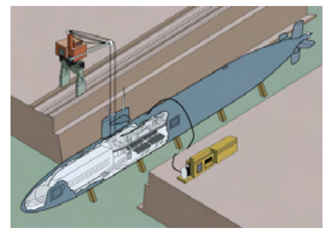
EB-PVD Facility

- 100 to 150 microns per minute deposition rate
- $1m^3$ chamber size
- Three independently controllable ingot feeders



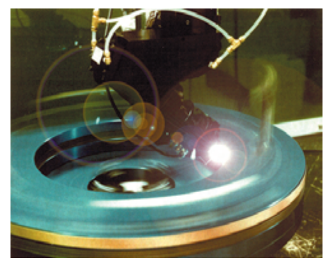
LASER PROCESSING

- 14-kW cw CO_2 laser system
- 2.0-kW cw and pulsed CO_2 laser systems
- 6-kW Diode-pumped cw Nd:YAG
- 3-kW cw Nd:YAG
- 400-W pulsed Nd:YAG
- 10-W Q-switched Nd:YAG
- Diode-pumped Q-switched Nd:YAG operating at 3rd harmonic
- 200-W excimer laser
- Laser Articulating Robotic System (LARS)
- Large-scale gantry
- Support equipment (e.g., robotic, linear and rotary workstations, etc.)



Technology Transfer Facilities

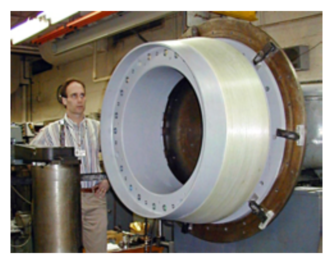
- Support equipment
- Two 3.0-kW cw Nd:YAGs at Puget Sound Naval Shipyard
- 2.4-kW cw Nd:YAG and robotic manipulator at Norfolk Naval Shipyard's Foundry and Propeller Center (Philadelphia, Pa.)
- 3.0-kW cw Nd:YAG laser at Naval Underwater Warfare Center, Keyport, Washington
- 25-kW cw CO_2 laser at ATS Corporation, Samford, Maine, with 24-foot gantry



ADVANCED COMPOSITES

Filament Winding Facility

- 4-axes computer controlled filament winder and ancillary support equipment for both "wet" and prepreg fabrication.



Layup/Autoclave Cure Facility

- Computer controlled autoclave, equipment and facilities for prepreg hand layup/cure of advanced composite materials and for structural bonding with film adhesives.

Machining Facility

- Specially-equipped shop for the machining of composite test specimens to ASTM/SACMA configurations.

Mechanical Testing Facility

- Instrumented impact, static and servo-hydraulic test frames for strength, fatigue and fracture mechnanics characterization of advanced composite material systems. Data used to generate material allowables databases.

Resin Transfer Molding Facility

- Resin meter/mix and vacuum equipment for fabricating hardware by both closed mold resin transfer molding (RTM)
- Open mold vacuum assisted resin transfer molding (VARTM) processes.

Ultrasonic Facility

- Ultrasonic NDE facilities and acoustic emission diagonostic equipment for quailty assurance inspection of composite and metallic structures, adhesive bondlines and in-service damage assessment.

Faculty, Staff, and Sponsors

APPLIED RESEARCH LABORATORY

Edward G. Liszka

B.S., Electrical Engineering, The Pennsylvania State University
M.S., Engineering Acoustics, The Pennsylvania State University
Ph.D., Applied Physics, The Catholic University of America

The eighth director of Penn State's Applied Research Laboratory, Dr. Liszka is the chief academic administrator of the Laboratory. He is responsible for directing the Laboratory's efforts in concurrence with Penn State's and the U.S. Navy's goal of being a naval technology base. As the largest of 20 interdisciplinary laboratories, centers, and institutes in the University's Inter-college Research Programs, ARL performs over 60 million dollars worth of research and development in the areas of undersea weapons guidance and control systems, advanced closed-cycle thermal propulsion systems for undersea weapons, propulsor technology, hydrodynamics for undersea vehicles and weapons, and materials manufacturing science for a wide-range of other sea-air-ground combat systems.

Prior to assuming directorship of ARL, Dr. Liszka served as Chief Scientist (Research and Technology) for the Office of Naval Research, which he assumed after serving as Associate Director for Undersea Systems at ARL.

Thomas M. Donnellan

B.S., Materials Engineering, Drexel University
M.S., Polymerics, Massachusetts Institute of Technology
Sc.D., Materials Science, Massachusetts Institute of Technology

Dr. Tom Donnellan is Associate Director for Materials and Manufacturing at ARL, Penn State. Prior to joining ARL, Dr. Donnellan served as chief scientist for materials at the Federal Bureau of Investigation. Prior to the FBI, Dr. Donnellan served as manager of structural sciences for Northrop Grumman Corporation. Previous to Northrop Grumman, Dr. Donnellan was the composites group manager for the Naval Air Development Center (NADC) at Warminster, Pennsylvania.

Robert B. Cook

B.S., Ocean Engineering, U.S. Naval Academy
M.S., Mechanical Engineering, Massachusetts Institute of Technology
Graduate, Defense Systems Management College

Mr. Bob Cook is director of Institute for Manufacturing and Sustainment Technologies. Prior to becoming director, Mr. Cook served as program manager for super-cavitation vehicles in ARL's Fluids and Structural Mechanics Division.

No stranger to ARL's naval tradition, Mr. Cook formerly served as a career nuclear submarine officer prior to joining the Applied Research Laboratory at Penn State in 1998. In addition to serving as commander of the USS *Sea Devil* (SSN 664), Mr. Cook served as a program manager within the Naval Sea Systems Command (NAVSEA), and also within the Program Executive Office (PEO) for Submarines.

Sean L. Krieger

B.S. Industrial Engineering, Cal Poly University
M.S. Management Engineering, University of Massachusetts

Mr. Krieger is the program manager for the iMAST Repair Technology (RepTech) effort at ARL Penn State. Mr. Krieger previously served in the Program Executive Office for the Virginia-class submarine program logistics office at the Naval Sea Systems Command. Prior to that DoN assignment, he served as a fleet representative on the maintenance and logistics staff of the Commander, Submarine Force Pacific Fleet (COMSUBPAC). Additionally, Mr. Krieger served a previous 10-year assignment at the Naval Undersea Warfare Center division maintenance and repair depot at Keyport, Washington.

Gregory J. Johnson

B.A. Pre Law, University of Hawaii
M.A. Education, Pepperdine University
Graduate, Defense Systems Management College

Mr. Johnson is the research institute administrator for the iMAST effort at ARL Penn State. Mr. Johnson previously served as executive assistant to the Deputy Assistant Secretary of the Navy for Research, Development & Acquisition. Prior to that assignment he served as the ground anti-armor program manager at the Marine Corps Systems Command. A former Naval Aviator, Mr. Johnson served in various operations and aircraft maintenance assignments to include maintenance test pilot positions with Japan Aircraft Company and China Airlines. Mr. Johnson is currently a Ph.D. candidate in public administration.

OFFICE OF NAVAL RESEARCH

Rear Admiral Jay M. Cohen

Rear Admiral Jay M. Cohen became the 20th Chief of Naval Research, commanding the Office of Naval Research (ONR), on June 7, 2000. As the Chief of Naval Research, RAdm Cohen manages the science and technology programs of the Navy and Marine Corps from basic research through manufacturing technologies.

In addition to his position as Chief of Naval Research, RAdm Cohen also assumed the duties of Director, Test and Evaluation and Technology Requirements in the office of the Chief of Naval Operations, and Deputy Commandant (Science and Technology), Headquarters, U.S. Marine Corps.

Rear Admiral Jay M. Cohen received his commission as an ensign upon graduation from the United States Naval Academy in 1968, where he was a Trident Scholar. After graduation, he qualified as a Navy diver with the SEALAB Group in San Diego, CA. Following training at Submarine School, New London, CT, he reported to USS *Dioden* (SS 349) in San Diego for duty as Supply and Weapons Officer during an extended WESTPAC deployment. He next studied at the Massachusetts Institute of Technology and Woods Hole Oceanographic Institution under the Navy's Burke Scholarship Program. He received a joint Ocean Engineering degree and Master of Science in Marine Engineering and Naval Architecture from MIT. Following Nuclear Power Training, he was assigned to the Engineering Department aboard USS *Nathanael Greene* (SSBN 636) (BLUE) in New London. He was next ordered to duty as Engineer Officer aboard USS *Nathan Hale* (SSBN 623) (BLUE) in overhaul at Bremerton, WA, subsequently changing homeport to Charleston, SC. Upon completion of that tour, he served on the staff of the Commander Submarine Force, U.S. Atlantic Fleet, from which he reported to USS *George Washington Carver* (SSBN 656) (GOLD) in New London as Executive Officer.

Rear Admiral Cohen commanded USS *Hyman G. Rickover* (SSN 709) from January 1985 to January 1988. Under his command, the USS *Rickover* completed a Post New Construction Shakedown availability in New London, changed homeport to Norfolk, VA and completed three deployments. The USS *Rickover* was awarded a Navy Unit Commendation, a Meritorious Unit Commendation, the SIXTHFLT "Hook'em" Award for ASW excellence, CINCLANTFLT Golden Anchor Award for retention excellence, the COMSUBRON 8 Battle Efficiency "E" Award, and was designated the best Atlantic Fleet Attack Submarine for the Battenburg Cup.

Following command, Rear Admiral Cohen served on the staff of Commander in Chief, U.S. Atlantic Fleet, as senior member of the Nuclear Propulsion Examining Board, and the staff of the Director of Naval Intelligence at the Pentagon as Director of Operational Support.

Rear Admiral Cohen commanded USS L.Y. SPEAR (AS 36) and her crew of 800 men and 400 women from March 1991 to April 1993. During his tour, the Spear was awarded the Submarine Force Atlantic Fleet Battle Efficiency "E" Award and conducted an unscheduled five-month deployment to the Persian Gulf in support of Operation Desert Storm that included repairs to over 48 U.S. and allied ships, recovery of an F/A-18 Hornet sitting in 190 feet of water off the coast of Iran and humanitarian projects in Kuwait City. SPEAR received a Meritorious Unit Commendation for the deployment which was the ship's first in eleven years. Additionally, SPEAR was the CINCLANTFLT 1991 Secretary of Defense Maintenance Award nominee and the only Atlantic Fleet tender recognized in two consecutive Golden Anchor competitions.

In April 1993, Rear Admiral Cohen reported to SECNAV staff for duty as Deputy Chief of Navy Legislative Affairs. In October 1997 he was promoted to the rank of Rear Admiral and reported to the Joint Staff for duty as Deputy Director for Operations. In June 1999 he assumed duties as Director Navy Y2K Project Office. In May 2000 he was ordered to duty as Chief of Naval Research.

Brigadier General Thomas D. Waldhauser, USMC

Brigadier General Waldhauser assumed his duties as Vice Chief of Naval Research on 27 August 2003. He also serves as Commander, Marine Corps Warfighting Lab in Quantico, VA.

A native of South St. Paul, Minnesota, General Waldhauser graduated from Bemidji State University in 1976. Upon graduation he was commissioned a second lieutenant in the United States Marine Corps.

His first assignment was with 1st Marine Division where he served with 3rd Battalion, 1st Marine Regiment and 1st Reconnaissance Battalion. From 1980 to 1984 Captain Waldhauser was assigned as the Commanding Officer, Marine Detachment, USS *Long Beach* (CGN-9) and subsequently served on the staff of the Commander, Amphibious Squadron Seven.

Reporting to the 2nd Marine Division in 1985, he served as a company commander in 3rd Battalion, 6th Marine Regiment. He was promoted to major and assigned as the operations officer for Battalion Landing Team 3/6 that deployed with the 26th Marine Amphibious Unit (Special Operations Capable) to the Mediterranean Sea as Landing Force, Sixth Fleet (LF6F) 2-87. Later, he served as Commanding Officer, 2nd Remotely Piloted Vehicle Company.

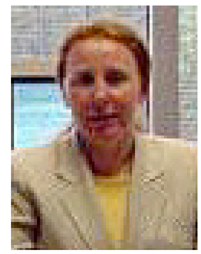
In 1988, Major Waldhauser was assigned as a faculty advisor and instructor at the Amphibious Warfare School, Quantico, Va. During this tour, he was a member of the Commander, U.S. Marine Central Command (Forward) staff aboard the USS *Blue Ridge* (LCC-19) during Operation Desert Shield/Desert Storm. In July 1992, Major Waldhauser joined the II Marine Expeditionary Force staff where he served in the G-3 Future Operations Branch.

Reporting to the 2nd Marine Division, Lieutenant Colonel Waldhauser assumed command of 3rd Battalion, 2nd Marine Regiment on November 5, 1993. During his tenure, BLT 3/2 deployed with the 26 MEU (SOC) as LF6F 2-94. In 1996, LtCol Waldhauser was assigned to Headquarters, U.S. Marine Corps, where he served as the Section Head, Ground Officer Assignments. In 1998, Colonel Waldhauser was assigned to the Joint Staff Combating Terrorism Directorate (J-34) where his billets included Division Chief and Assistant Deputy Director.

He assumed command of the 15th MEU (SOC) on July 24, 2000. During this tour, the 15th MEU (SOC) participated in combat operations in Southern Afghanistan for Operation Enduring Freedom and in Iraq for Operation Iraqi Freedom.

Colonel Waldhauser has attended U.S. Army Ranger School, Jumpmaster School, Amphibious Warfare School, Marine Corps Command and Staff College and the National War College where he earned a Masters Degree in National Security Strategies.

Lynn Torres



Ms. Torres is the acting director of the U.S. Navy's Industrial and Corporate Program Department, Office of Naval Research. Ms. Torres is responsible for the Navy's Independent Research and Development, Manufacturing Science and Technology, Small Business Innovation Research, and Cooperative Research and Development Agreements programs. Ms. Torres has extensive service with the Department of the Navy and the Office of Naval Research. Prior to assuming her current assignment, Ms. Torres led ONR's Expeditionary Logistics Future Naval Capabilities (FNC) integrated product team (IPT).

A graduate of Montana State University with a B.S. degree in electrical engineering, Ms. Torres previously worked at the Naval Facilities Engineering Service Center at Port Hueneme (CA), supporting underwater construction tool suite development, as well as amphibious and expeditionary engineering programs for the Marine Corps that included radio-frequency technology, magnetic mine countermeasures, and material-handling equipment.

Adrienne Gould

Ms. Gould is the acting director for the U.S. Navy Manufacturing Technology (ManTech) Division, Office of Naval Research. Ms. Gould is responsible for managing the ManTech Program, Best Manufacturing Program, and the Navy's nine Center's of Excellence. She is tasked with developing, coordinating and integrating program policy, procedures, and content throughout the U.S. Navy, and works in cooperation with the joint services and applicable agencies. She is also the Navy's representative to the Joint Directors of Laboratories Manufacturing Science and Technology Panel.

A native of Philipsburg, PA, Ms. Gould attended Radford University in Virginia before joining the Office of Naval Research.

John Carney

Mr. Carney is the program manager for iMAST's ongoing Navy ManTech program effort at ARL Penn State. Mr. Carney provides financial and programmatic oversight to iMAST, as directed by the Office of Naval Research.

A native of Sterling, Virginia, Mr. Carney received a B.S. degree in industrial engineering and operations management, as well as an M.S. degree in engineering management, both from Virginia Tech. Mr. Carney's technical interests include shipbuilding technology.

MARINE CORPS SYSTEMS COMMAND

(iMAST Lead Systems Command)

Brigadier General William Catto, USMC

Brigadier General Catto is the Commander, Marine Corps Systems Command at Quantico, VA. The Marine Corps Systems Command (MARCORSYSCOM) serves as the lead systems command for the Institute for manufacturing and Sustainment Technologies (iMAST), a U.S. Navy ManTech Program at ARL Penn State.

A 1973 graduate of Bethel College, General Catto received his M.A. from Webster University in 1985. He was commissioned a second lieutenant after completing Officer's Candidate School in 1973 and designated a Naval Aviator in December 1974.

Following initial qualification in the CH-46, Brigadier General Catto was assigned to Marine Medium Helicopter Squadron-161, MCAS Tustin, Calif., where he served in the Aircraft Maintenance Department. Later reassigned to duty in Headquarters and Maintenance Squadron Sixteen, he served as the Airframes Division Officer. In the spring of 1977, he was transferred to the Naval Aviation Training Command for duty as a flight instructor with Training Squadron Two located at NAS Whiting Field, FL.

Returning to MCAS Tustin in 1980, Brigadier General Catto joined Marine Medium Helicopter Squadron 268 where he made several deployments to the Western Pacific, and attended the Weapons Tactics Instructor Course. In May 1985, he transferred to the 1st Marine Division for duty with the 7th Marine Regiment. During this ground tour Brigadier General Catto served initially as the Air Officer and then as the Regimental Operations Officer. He remained with the Regiment until July 1988 when he departed to attend the Marine Corps Command and Staff College at Quantico, VA.

Following Command and Staff College, Brigadier General Catto was assigned to Headquarters, U.S. Marine Corps, Washington, D.C., where he worked in Manpower as the Rotary Wing Majors Assignments Officer, and later as the Administrative Assistant to the Deputy Assistant Chief of Staff for Aviation. Returning to MCAS Tustin in 1990, Brigadier General Catto was assigned as the Executive Officer and then Commanding Officer of Marine Medium Helicopter Squadron-163 where he deployed twice in the MEU(SOC) rotation. Following his tour as an aviation combat element commander with the 11th MEU(SOC), Brigadier General Catto was assigned to the RAND Corporation in Santa Monica, CA, as a Marine Corps Fellow. In July 1995, he was again ordered to duty in Washington, D.C. and assigned to the Office of the Secretary of Defense; Programs, Analysis, and Evaluations; Weapons Systems Cost Analysis Division. Here he served as an operations and support cost analyst and worked on the Milestone Reviews of the C-17, F-22, V-22, and H-1 4BN/4BW Remanufacture Program. In May of 1998, Brigadier General Catto was assigned as Commanding Officer, Marine Aviation Weapons and Tactics Squadron One at MCAS Yuma, AZ.

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iMAST

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llm1@psu.edu

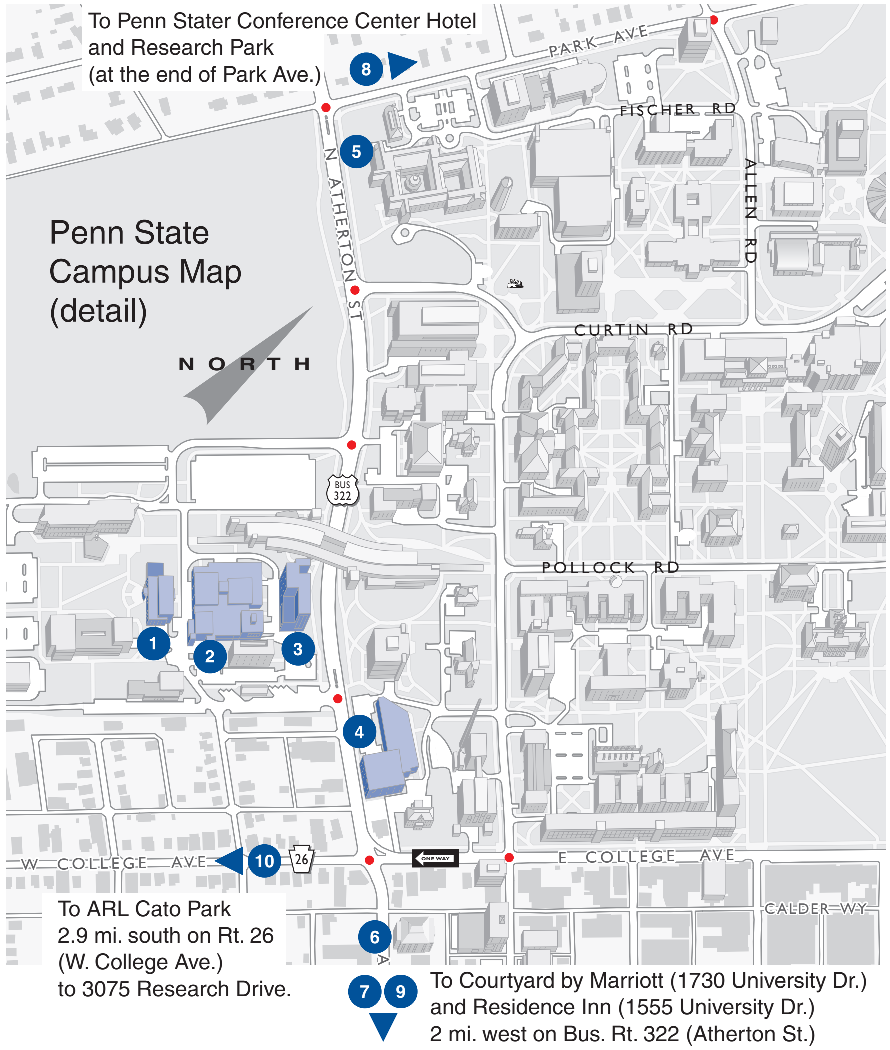
iMAST on the World Wide Web:
www.arl.psu.edu/capabilities/mm_imast.html

The iMAST World Wide Web site provides an overview of the Institute and its technical thrust area projects, information on upcoming events, facilities, and newsletters.

Traveling to ARL Penn State

Area Code (814)

1. Applied Science Building, 863-9825
2. Research West Building
3. ARL Water Tunnel, 865-1741
4. Applied Research Laboratory, 865-3031
5. Nittany Lion Inn, 865-8500
6. The Atherton Hotel, 231-2100
7. Courtyard by Marriott, 238-1881
8. Penn Stater Conference Center Hotel, 863-5000
9. Residence Inn, 235-6960
10. ARL Cato Park, 863-9751



FROM NEW YORK CITY
The suggested route is via the George Washington Bridge to I-80. In Pennsylvania, exit from I-80 at Exit 24 (Bellefonte) and follow Route 26 south to State College.

FROM PHILADELPHIA
There are two routes. (1) Take the Northeast extension of the Pennsylvania Turnpike (I-76) to I-80. From I-80, exit at Exit 24 (Bellefonte). Follow Route 26 to State College; or (2) take the Schuylkill Expressway to the Pennsylvania Turnpike (I-76). Use Exit 19 (Harrisburg East) follow I-283 to I-83 and proceed north on I-83 to the I-81 interchange. Then follow I-81 west to Route 322/22 west Exit. Proceed west on Route 322 through Lewistown to State College.

FROM PITTSBURGH
Follow Route 22 to Duncansville, Route 220 (bypassing downtown Altoona and Tyrone) through Port Matilda and then Route 322 (Business–also called North Atherton Street) to State College. A scenic route follows Route 22 beyond Duncansville to Water Street, Route 45 to Pine Grove Mills and Route 26 to State College.

FROM WASHINGTON, D.C.
Several routes are available: (1) Take Route I-270 to Frederick, I-70 to Breezewood, Pennsylvania Turnpike (I-76) for 18 miles to Bedford/Altoona exit (Exit 11). (The toll fee is approximately 80 cents.) Follow Route 220 to Port Matilda and then Route 322 Business (also called North Atherton Street) to State College; or (2) follow I-270 to Frederick, Route 15, past Gettysburg, through Camp Hill to Route 322 west to State College passing by Lewistown; or (3) take I-95 or the Baltimore/Washington Parkway to Baltimore, west loop I-695 to I-83 north. Continue on I-83 north to I-81 interchange. Then follow I-81 west to Route 322/22 Exit. Proceed west on Route 322 passing Lewistown to State College.

FROM THE WEST
Take I-80 to Exit 20 (Woodland) just east of Clearfield, then Route 322 east to State College. One may also exit I-80 from Bellefonte and follow Route 26 south to State College.

BY BUS
Trailways and Greyhound Lines connections are available to and from State College.
Trailways (814) 238-7362
Greyhound (814) 238-7971

BY PLANE
Daily flights from Pittsburgh, Philadelphia, Detroit, Harrisburg, Dulles, Baltimore, and Cincinnati serve the State College area through the University Park Airport (State College), located five miles from campus. Limousine or taxi service is available for all flights.
Reservations and information:
USAir Express (800) 428-4253
United Express (800) 241-6522
Northwest Airlink (800) 225-2525
Delta Express (800) 221-1212

Private or chartered aircraft may fly into University Park Airport (State College). Please call (814) 355-5511 to make arrangements. Facilities exist for overnight accommodations, fuel and maintenance service.

RENTAL CARS
At the airport. Reservations and info:
National (814) 237-1771
Hertz (814) 237-1728

HOTELS (partial listing)
The Nittany Lion Inn (on campus)
(800) 233-7505 (814) 865-8500

Penn Stater Conference Center Hotel
(PSU Research Park, shuttle, car/cab)
(800) 893-4602 (814) 863-5000

The Atherton (walk to campus)
(800) 832-0132 (814) 231-2100

Courtyard by Marriott (shuttle)
(800) 321-2211 (814) 238-1881

Hampton Inn (car/cab)
(800) 426-7866 (814) 231-1590

Days Inn Penn State (car/cab)
(800) 258-3297 (814) 238-8454

Residence Inn by Marriott (shuttle, car/cab)
(800) 331-3131 (814) 235-6960

About ARL Penn State

Solving challenges for the U.S. Navy for over a half a century, the Applied Research Laboratory at Penn State has demonstrated innovation and practicality in technology-based research. The Applied Research Laboratory is one of four U.S. Navy academic research centers in the country. While ARL has served as a Center of Excellence in undersea technology, it has also facilitated Penn State in becoming second among U.S. universities in industrial R&D funding.

Its broad-based effort is supported by a full-time complement of more than 500 scientists, engineers, technicians, and support staff, in addition to 200 associate members within the university. Through its affiliation with various colleges of Penn State, other universities, and consortia, it has extended capabilities to manage and perform interdisciplinary research.

The Applied Research Laboratory's charter includes and promotes technology transfer for economic competitiveness. This focus supports congressional and DoD mandates that technology from federally-funded R&D be put to dual use by being transferred to the nation's commercial sector.

ARL Washington D.C. Office

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ARL Organization by Core Competency

PENNSTATE ARL

CORE CENTERS
- Drivetrain Technology Center
- Electro-Optics Science & Technology Center
- Institute for Emerging Defense Technologies
- Institute for Manufacturing & Sustainment Technologies
- Navigation Research and Development Center

MAJOR PROGRAMS
- Ausform Gear Finishing
- Night Vision and Fiber Optics
- Force Protection
- Non-Lethal Defense
- Repair Technologies
- GPS Development

Undersea Systems

CORE COMPETENCIES
- Autonomous Control and Intelligent Systems
- Systems Analysis
- Energy Science and Power Systems
- Acoustics
- Emerging Defense Technologies

MAJOR PROGRAMS
- Long-Endurance, Low-Frequency, Acoustic Source LELFAS (ATD)
- Anti-Torpedo Torpedo (ATD)
- Multi-Platform Broadband Processing
- Vortex Combustor Power Source
- Wick Combustor Power Source(UUV)
- HYDROX Power Source
- NOO Unmanned Vehicle

Information and Network Systems

CORE COMPETENCIES
- Information Science and Technology
- Navigation Research and Development Center
- Communications Science and Technology

MAJOR PROGRAMS
- Condition-Based Maintenance
- High-Accuracy Fiber-Optic Gyro
- Robust GPS Communications
- Integrated Air Defense Support
- Ocean Sampling Mobil Network
- Damage Control Automation for Reduced Manning

Fluids and Structural Mechanics

CORE COMPETENCIES
- Fluid Mechanics
- Flow and Structural Acoustics
- Computational Mechanics
- Hydroacoustics

MAJOR PROGRAMS
- Virginia Class Propulsor (NSSN)
- Seawolf Quieting (SSN-21)
- Super-Cavitating Vehicle
- NOO Unmanned Vehicle
- Reactor Main Coolant Pump Loop (SEA 08)
- Flow Control

Materials and Manufacturing

CORE COMPETENCIES
- Manufacturing Systems
- Materials Processing
- Laser Processing
- Drivetrain Technology Center
- Electro-Optics Center
- Advanced Composites Materials
- Repair Technologies
- Systems and Operations Automation

MAJOR PROGRAMS
- Ausforming Finished Bearing Races (AAAV)
- Ausform Gear Qualification (DUST/MV-22)
- Spray Metal Forming (JSF)
- Cold Gas Dynamic Spraying (AAAV)
- Femtosecond Laser Processing
- Electron Beam-Physical Vapor Deposition

FY04 ManTech Projects

iMAST ManTech Projects

A0909 F/A-18 F404 Engine Fretting and Low Cycle Fatigue Amelioration
A0933 Aircraft Carrier Arresting Gear Poured Cable End Sockets
C0934 AAV Enhanced Applique Armor Kit (EAAK) Product Improvement
A0948 Smart Sensors/Actuators
S0949 Propulsor Affordability Initiative
S0968 Automated Paint Application Containment & Treatment System (APACTS) Process Development
A0970 Functional Gradient Thermal Barrier Coating for F405 Turbine Engines
A0974 High Rate Machining of Ti Blisks and Disks
S1017 Hot Section Corrosion Protection for 501-K34 Gas Turbine
S1019 DDX: Collarless Construction
S1021 Shipbuilding Initiative: Advanced Steel Fabrication Processes
S1033 DDX: CNC Thermal Plate Forming
S1034 Overspray Elimination Through Development of High Transfer Efficiency Painting Technologies
S1036 Shipbuilding Initiative: Cluster Based Manufacturing Through Integrated Product and Process Simulation
S1038 Shipbuilding Initiative: Hybrid Welding of Ship Structures
S1039 Shipbuilding Initiative: Flash-Rust Impact on Coatings

iMAST RepTech Projects

R0834 Rapid Response Projects
S0962 HAZMAT Analyzers for Rapid On-Site Analysis
S0994 VLS Tube Repair
A1014 Helicopter Blade Refurbishment
S1016 Polycan Fabrication
C2026 M198 Howitzer Mechanism Tester
A2028 CH-46 Gear Repair
S2025 Submarine Alignments and Inspections

NAVY MANTECH
manufacturing technology program

Technology Transfer Event Participation

Defense Manufacturing Conference '03, Dallas, TX

American Helicopter Society Forum 60, Washington D.C.

Showcase for Commerce, Johnstown, PA

Navy League SeaAirSpace Expo 2004, Washington D.C.

ICALEO 2004, Dearborn, MI

ShipTech 2004, Biloxi, MS

U.S. Coast Guard Expo, Baltimore, MD

TechTrends 2004, Wilmington, DE

Showcase for Commerce Armstrong County, Kittanning, PA

MarCorSysCom Industry Day, Crystal City, VA

ONR Naval-Industry R&D Conference 2004, Washington D.C.

Marine Corps League Modern Day Marine Expo, Quantico, VA

Shipyard Applications for Industrial Lasers Conference 2004, Williamsburg, VA

PENNSTATE ARL

Institute for Manufacturing and Sustainment Technologies

iMAST

A U.S. Navy Manufacturing Technology Center of Excellence

QUARTERLY

2003 No.3

Sound Waves Send Chill Through ONR

Penn State Applied Research Lab engineers have produced a thermoacoustic refrigeration unit that has far-reaching implications for both Navy and Marine Corps weapon systems. Proof of concept has been achieved for a cooling devise that substitutes sound waves for environment-damaging chemical refrigerants. Refrigerants cause pollution. Chlorofluorocarbons (CFCs) once used in refrigeration units are long gone. While the new chemicals substituting for CFCs may not affect Earth's ozone layer, pollution problems still exist. Beyond the environmental aspect, the system also allows for unique design opportunities within limited space structures in such systems as ships and ground combat vehicles.

So how does the system work? The answer is noise; really loud noise readily generated aboard Navy and Marine Corps fighting machines. When inert gases are exposed to high-amplitude sound energy, a thermo-acoustic effect takes place. The refrigeration unit consists of a souped-up amplifier and a unit containing inert pressurized gases. High-volume sound hitting the inert gases in the freezer unit is enough to lower the temperatures to around minus-8 degree F.

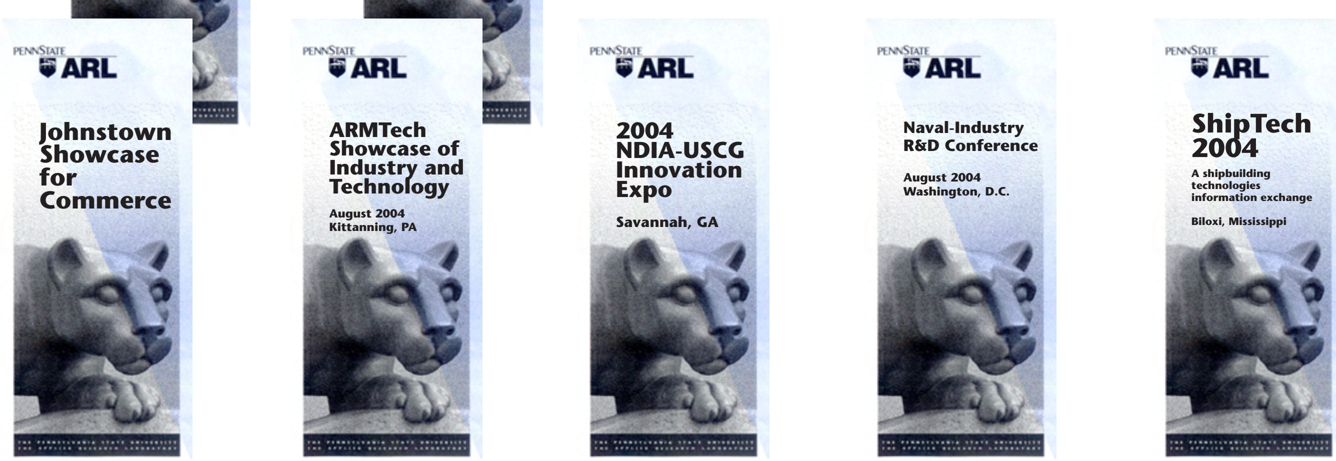
According to Steve McElvany, a program manager within the Office of Naval Research, "The Navy has been looking for years for alternatives to freon-based cooling aboard Navy ships to save energy as well as the environment."

ARL researcher Steve Garrett notes, "What began as basic research on the fundamental connections between sound waves and heat transport, funded by the Office of Naval Research, is getting closer to providing an environmentally benign substitute for traditional engine and refrigeration technology."

In addition to funding by ONR, Ben & Jerry's Ice Cream (a division of Unilever) is also providing financial support. Technologies like thermoacoustic refrigeration are ideal for Navy ManTech implementation.

If you are interested in obtaining more information about this technology, contact Robert Keolian at <keolian@psu.edu> or call him at (814) 865-1365. For more information on other unique ARL technologies available for ManTech, contact iMAST's director, Bob Cook at <rbc5@psu.edu>, or call (814) 863-3880.

Focus On Repair Technology



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U.Ed. ARL 04-02